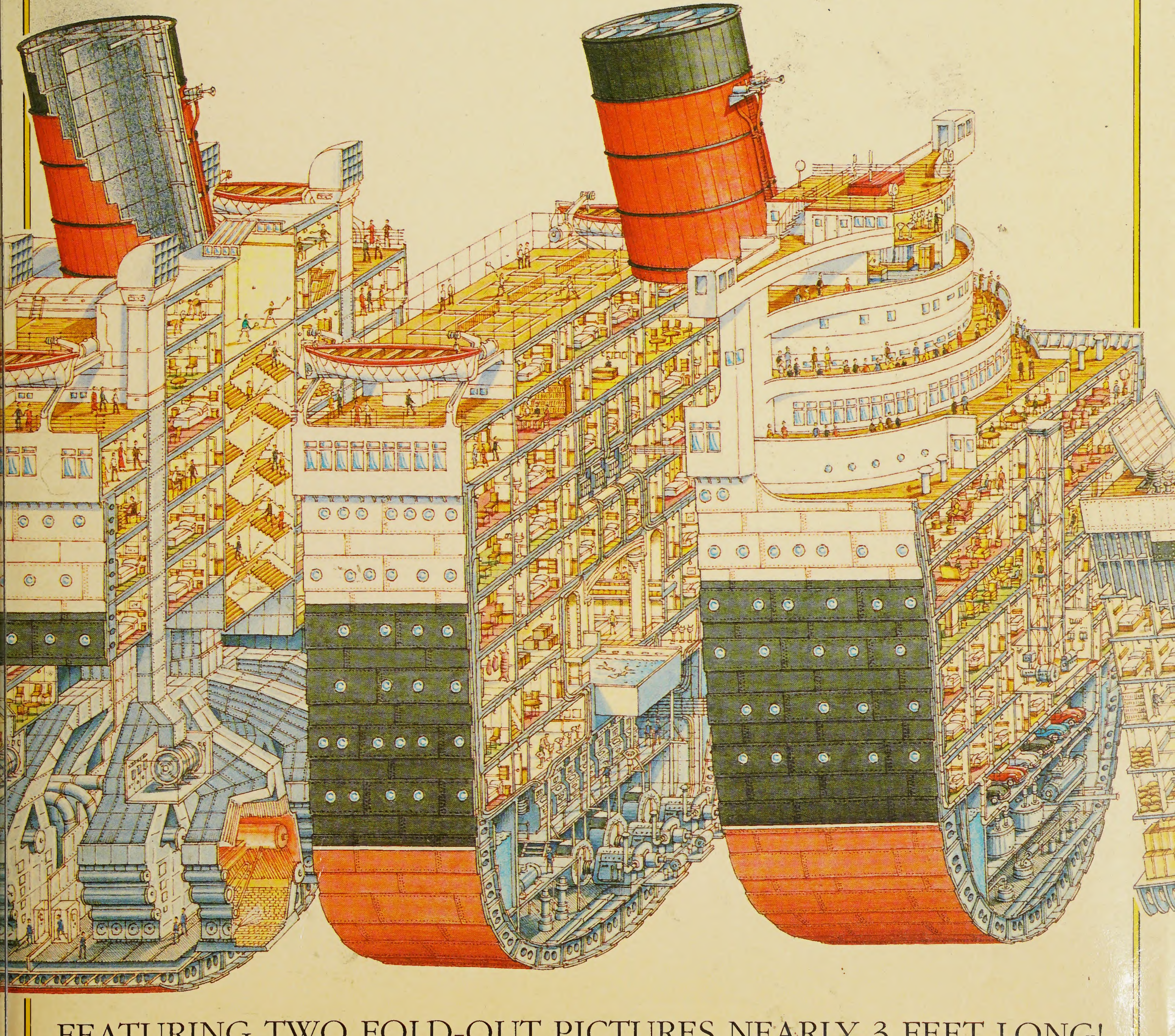
STEPHEN BIESTY'S

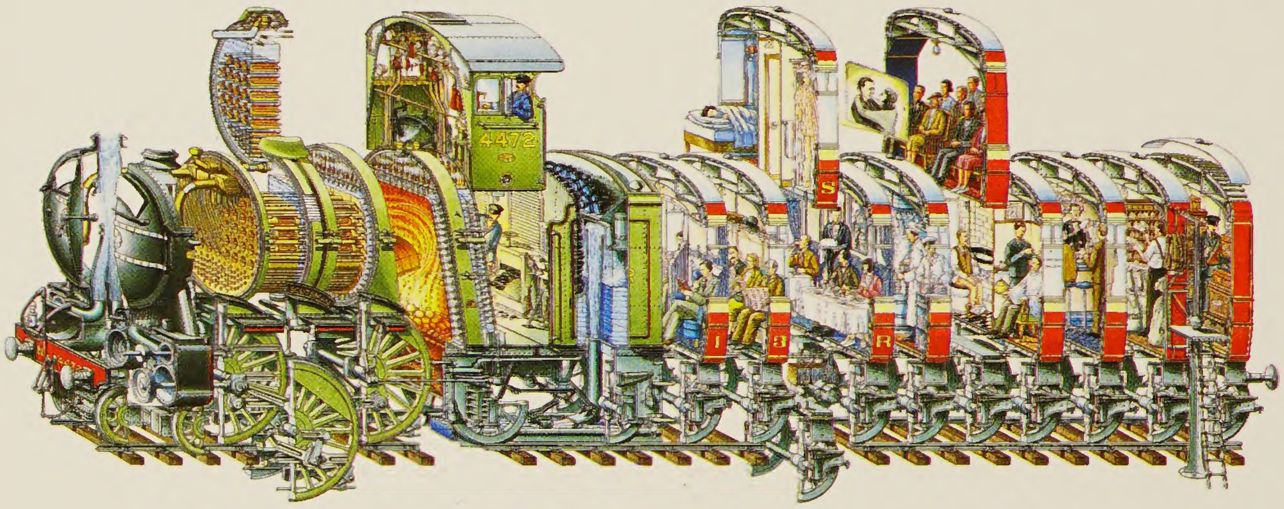
INCREDIBLE CROSS-SECTIONS



FEATURING TWO FOLD-OUT PICTURES NEARLY 3 FEET LONG!

STEPHEN BIESTY'S
INCREDIBLE
CROSS-SECTIONS

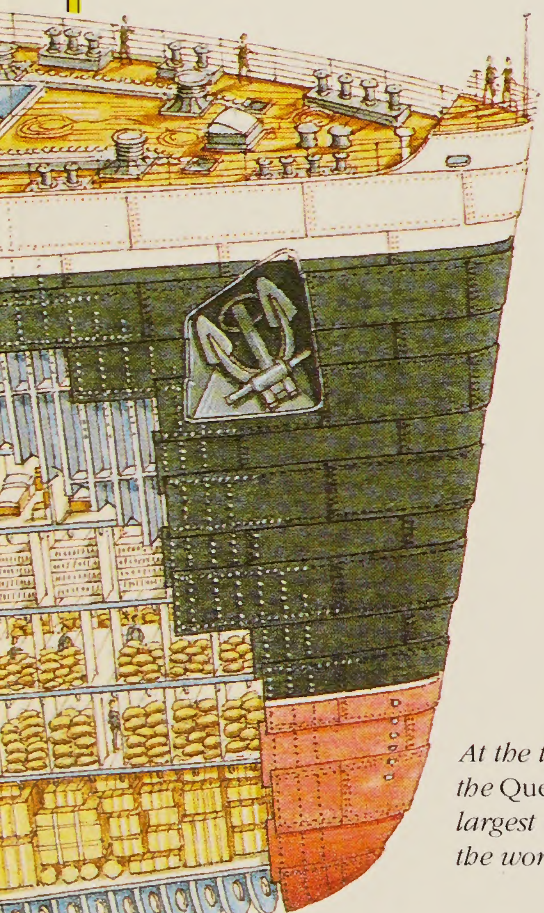
FROM A SPANISH GALLEON TO A BOEING 747, FROM A
MEDIEVAL CASTLE TO A SOVIET TANK, SEE INSIDE
18 AMAZING BUILDINGS AND MACHINES



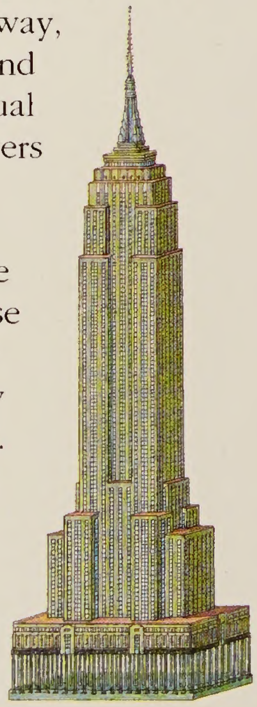
Passengers on the Flying Scotsman, *a 1930s steam train, enjoyed first-class meals, hot showers, radio broadcasts on headsets, and the latest films shown in a special movie car.*

Here is a very special picture book that features the extraordinary cutaway illustrations of Stephen Biesty. Page after page of amazing, original artwork reveals just what goes on inside a subway, castle, jumbo jet, ocean liner, oil rig, and more. Each illustration is based on actual plans and architects' drawings, so viewers see inside *real* ships, buildings, and machines. With humor and incredible attention to detail, Biesty reveals all the hidden features that we might otherwise never see. Two pages — *Ocean Liner* and *Steam Train* — fold out to display fantastic pictures nearly three feet long.

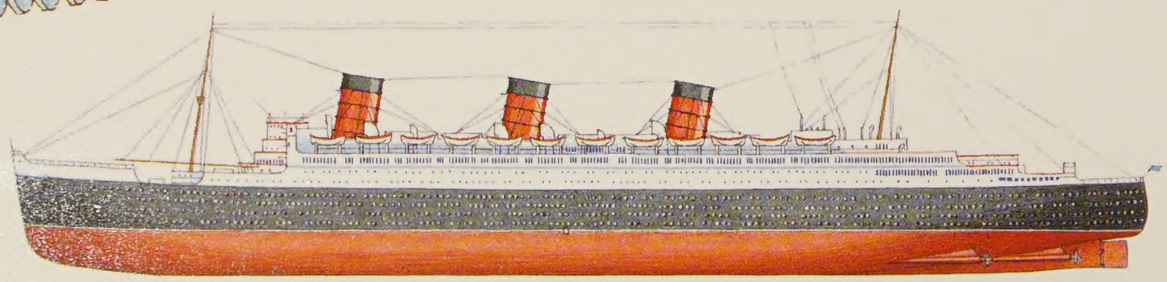
Supported by lively text and packed with fascinating facts, this book will appeal to anyone who has ever wondered what goes on behind the scenes.



At the time it was built, the Queen Mary *was the largest ocean liner in the world.*



The Empire State Building is lined with 10 million bricks.



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STEPHEN BIESTY'S INCREDIBLE CROSS-SECTIONS

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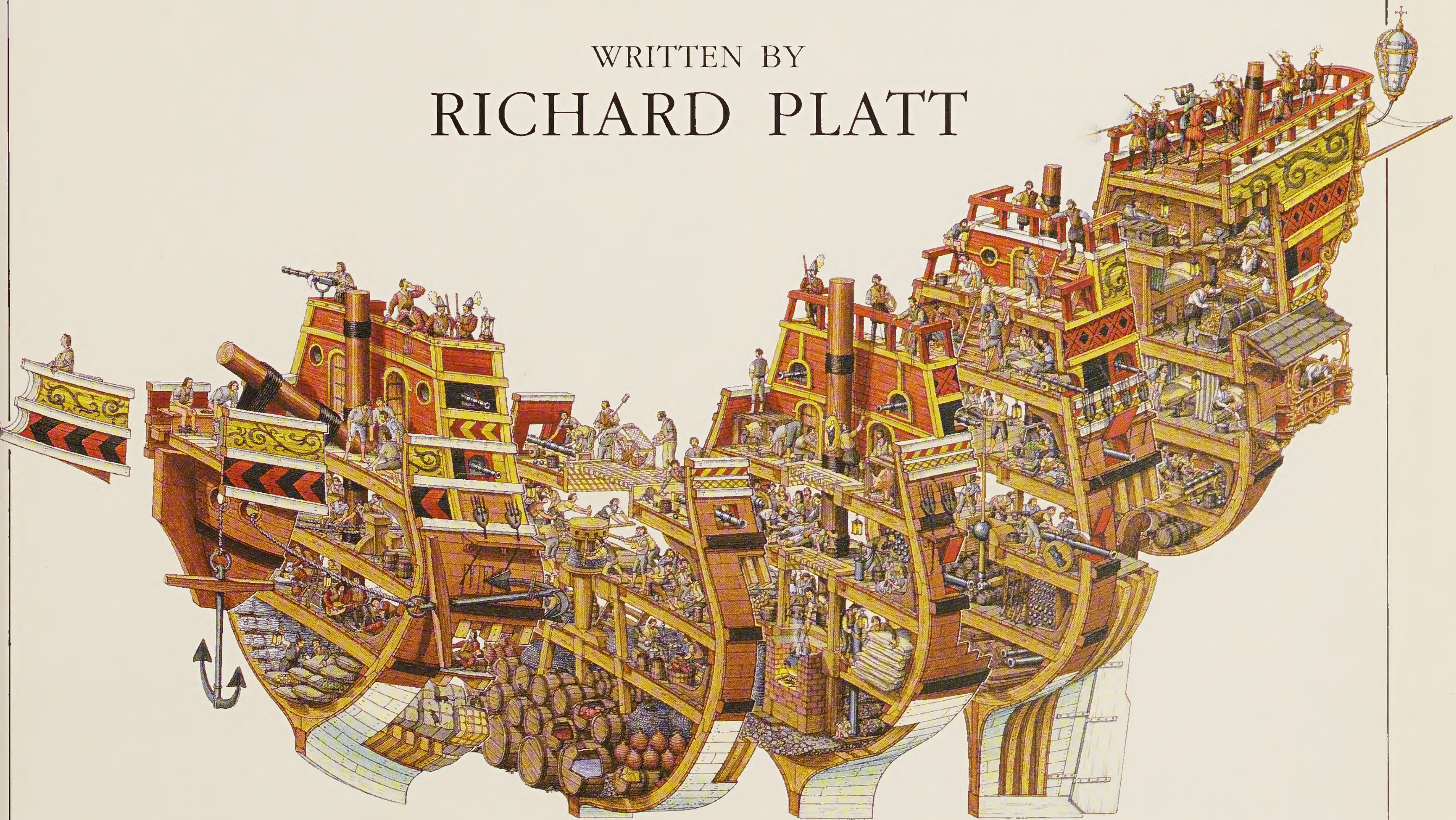
STEPHEN BIESTY

WRITTEN BY

RICHARD PLATT



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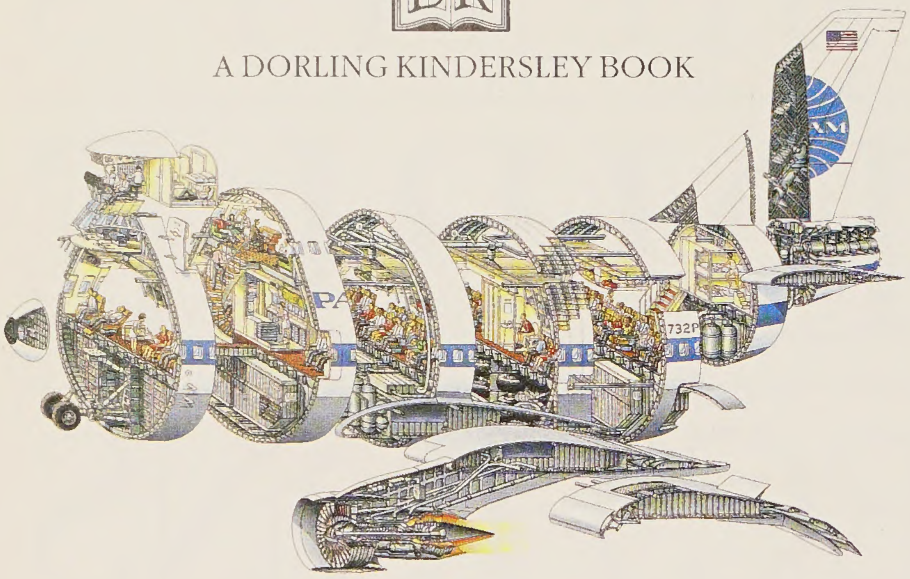

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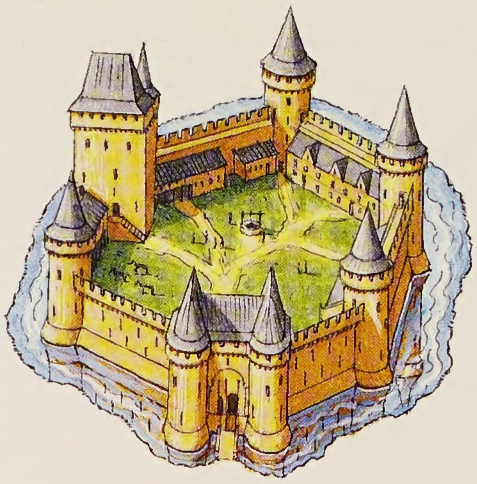

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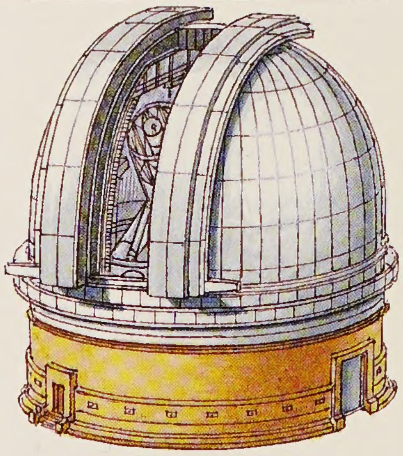

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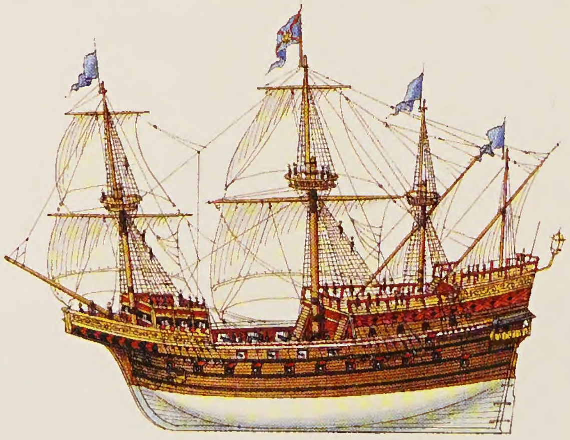

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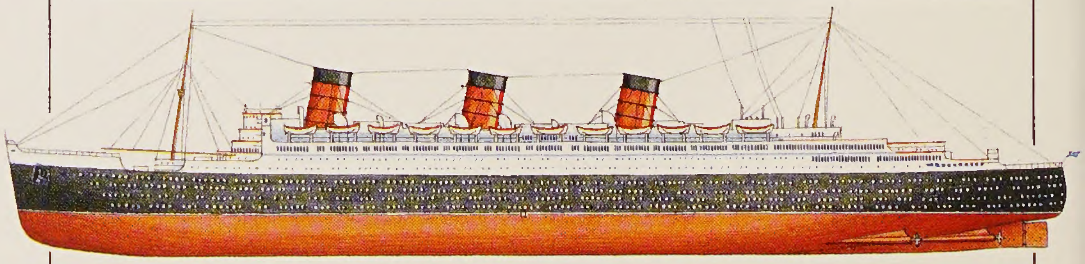

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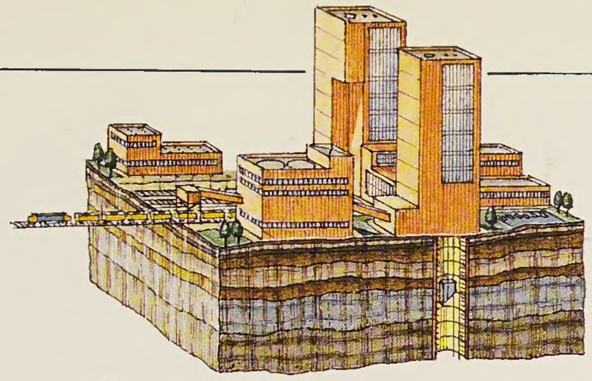

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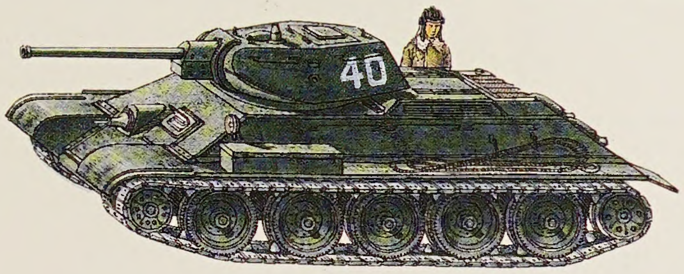

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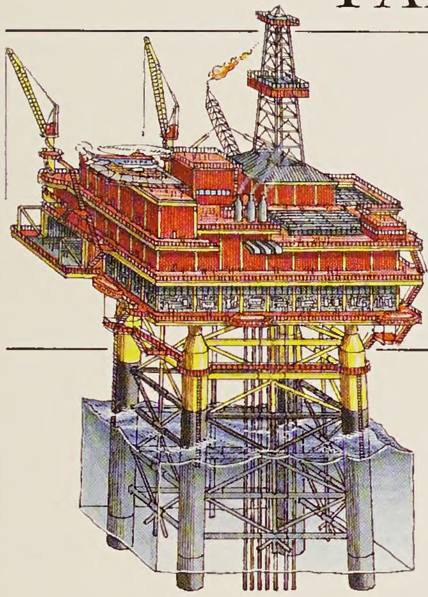

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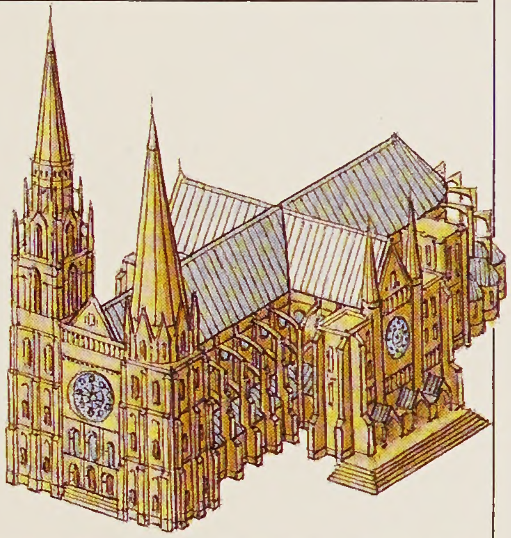

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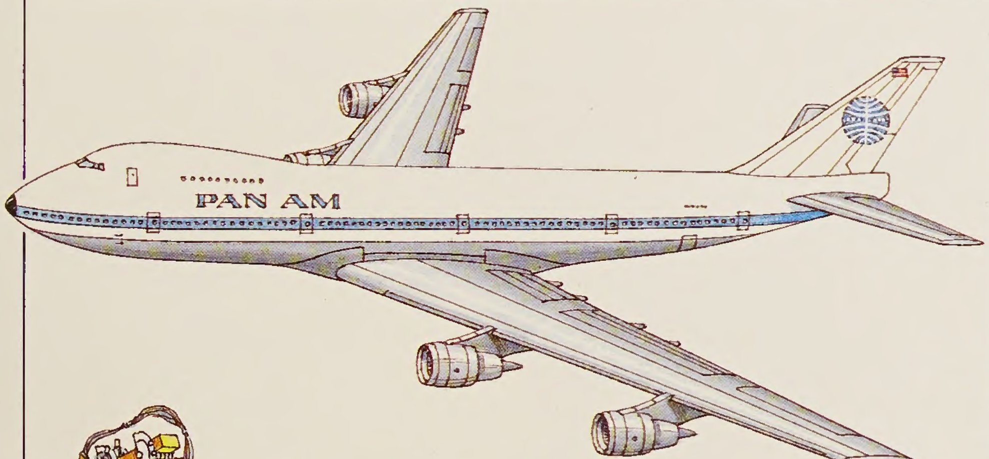

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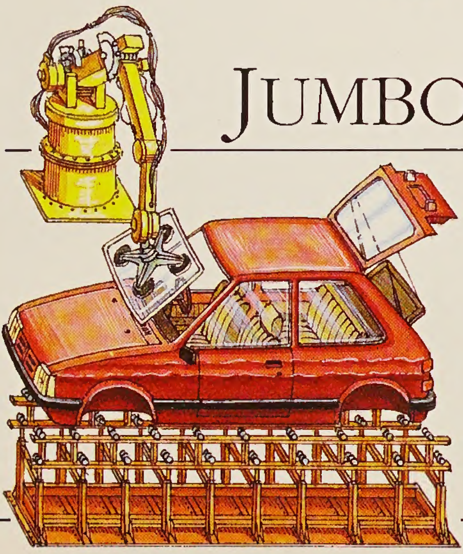

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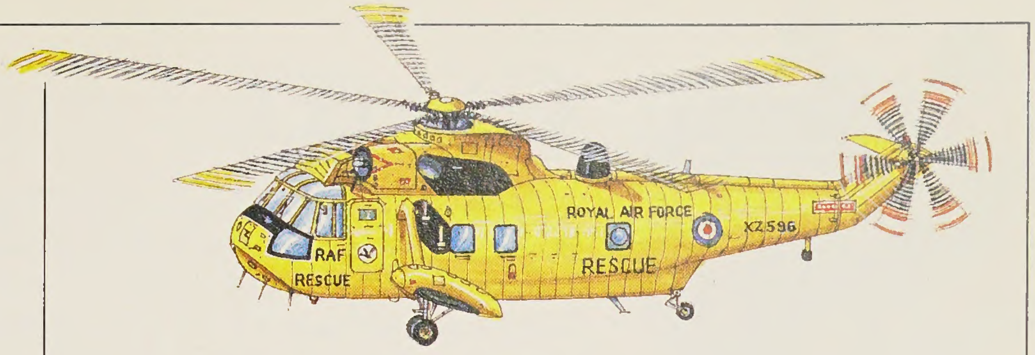
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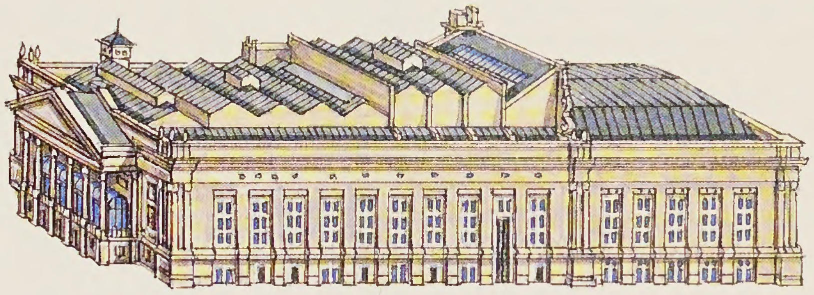

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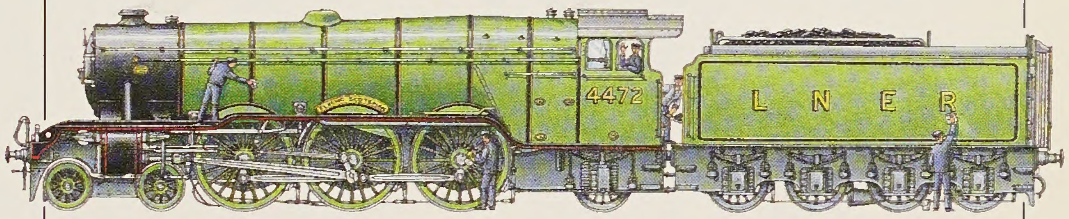

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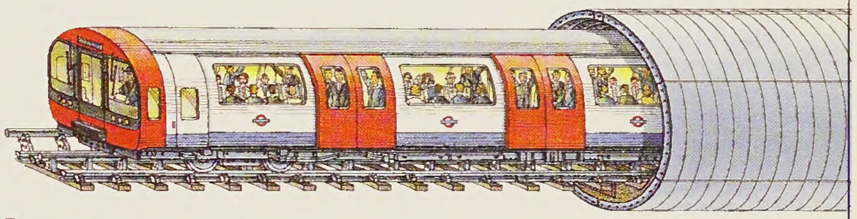

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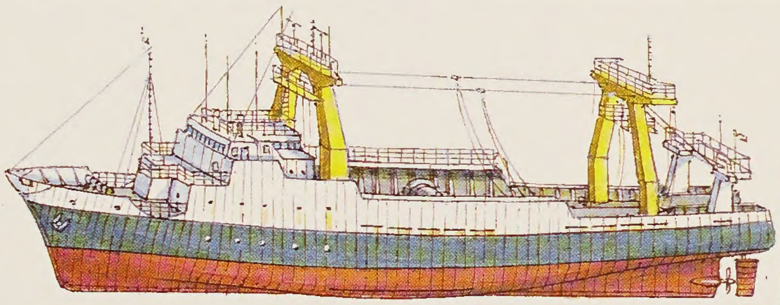

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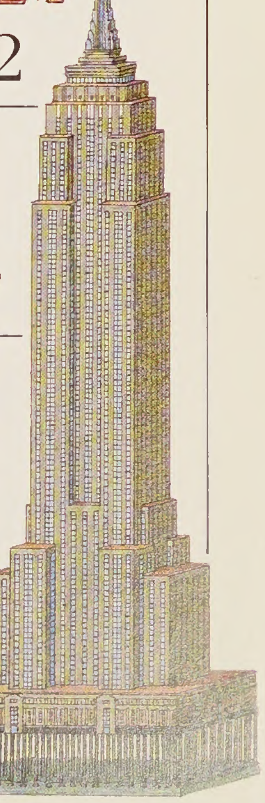

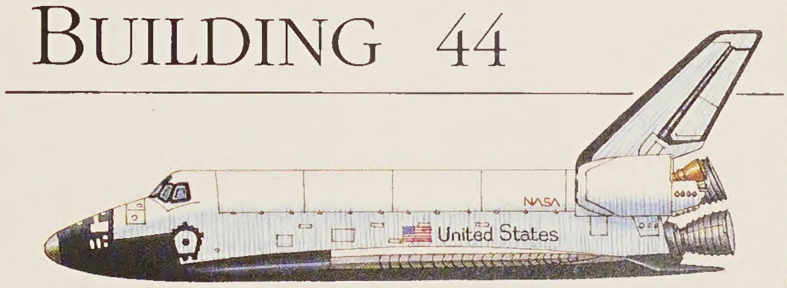
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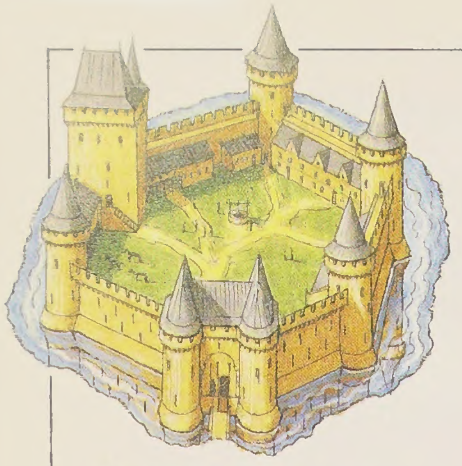
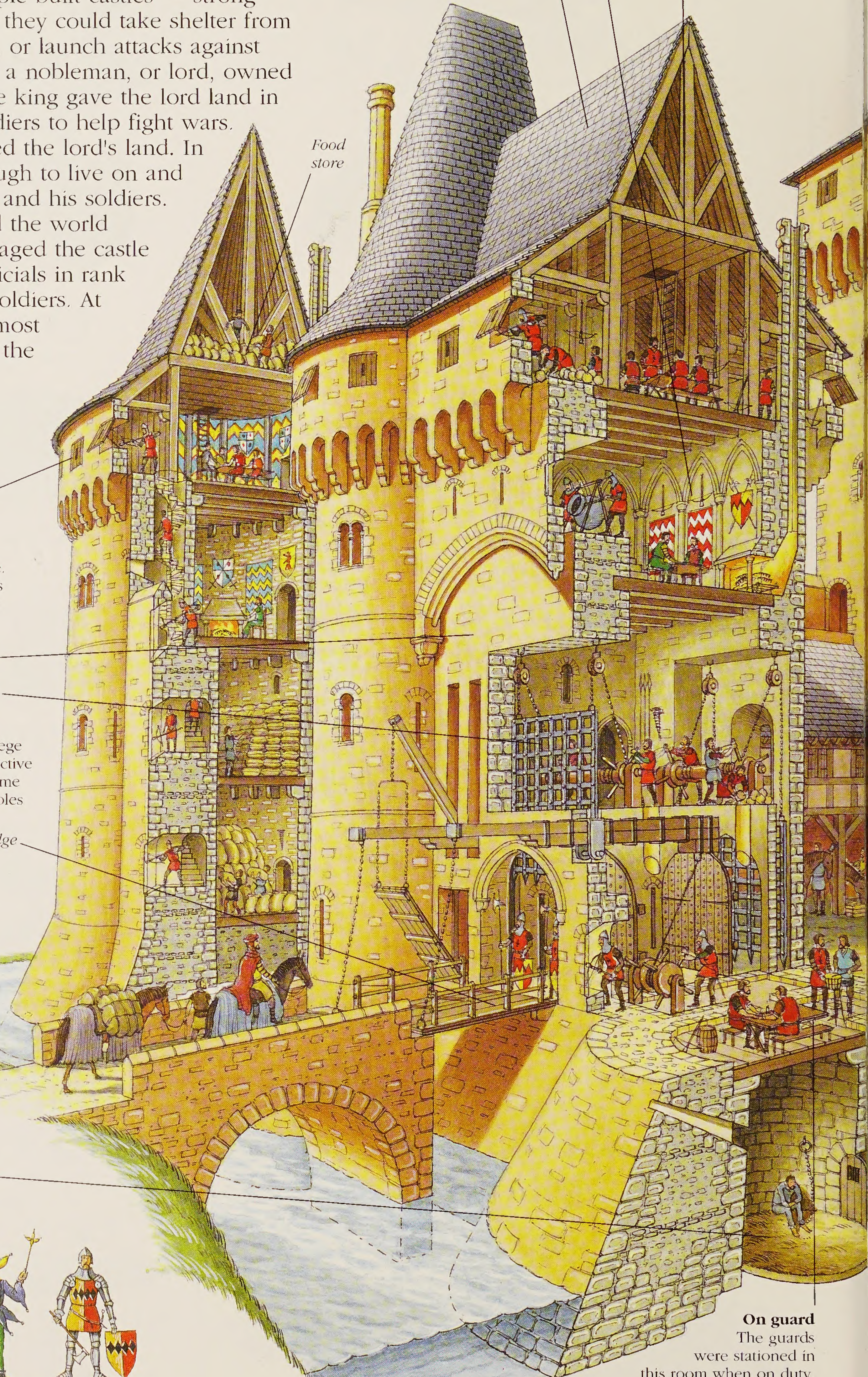


Many 14th-century castles had thick outer walls, which enclosed a central open area.

CASTLE

Hundreds of years ago, life in Europe was dangerous and wars were common. So powerful people built castles — strong homes where they could take shelter from their enemies, or launch attacks against them. Usually a nobleman, or lord, owned the castle. The king gave the lord land in return for soldiers to help fight wars. Tenants farmed the lord's land. In return for their labor, they earned enough to live on and were protected in wartime by the lord and his soldiers. Society inside the castle walls mirrored the world outside. The lord and his officials managed the castle and the lands around it. Below the officials in rank were priests, important servants, and soldiers. At the bottom of castle society were the most humble workers, such as laborers and the cesspool cleaner shown below.



Deadly fire
Narrow slits in the castle walls allowed archers to fire freely, while protecting them from incoming arrows. From the overhang at the top of the walls, defenders could drop stones on attackers' heads to stop them from climbing the walls.

Gatehouse
The only way into the castle was through the gatehouse. This was the weakest point in the castle wall. Defenders on the top of the wall fired arrows at attackers who got too close, or threw boiling water down on them. The defenders could also lower a huge gate, called a portcullis, which trapped their attackers.

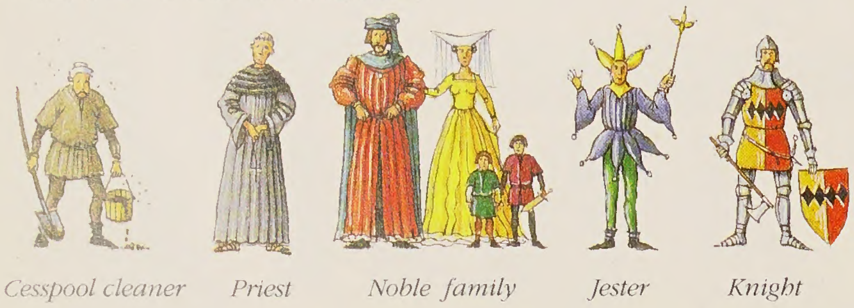
Getting inside
Capturing a castle was difficult. Attackers had to try to tunnel under the walls, trick the people inside, or lay siege and starve them out to gain access. Castles were an effective defense until about 350 years ago, when gunpowder came into wide use and attacking armies could easily blow holes in the strongest castle wall.

A moat point
Another defense was a water-filled trench called a moat, which surrounded the castle. The moat was a difficult hurdle for attackers, and also stopped them from digging a tunnel under the walls. The road to the gatehouse crossed the moat by means of a hinged drawbridge, which could be raised.

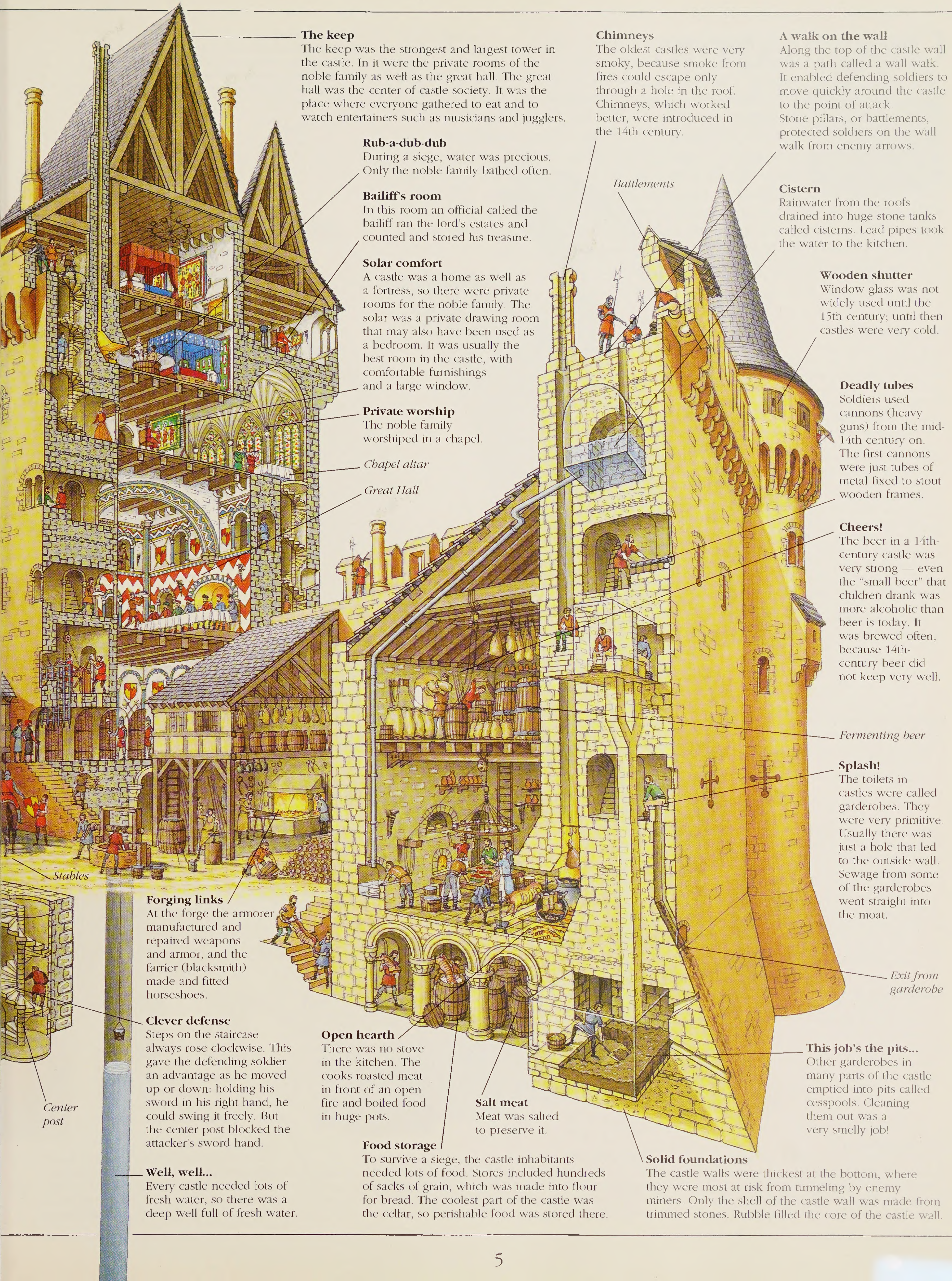
Doing time
Prisoners were locked up in an underground cell, called a dungeon. Oubliettes, or secret dungeons, got their name from the French word *oublier*, meaning "to forget." Oubliettes were reserved for the most hated prisoners. Their captors locked them up — and forgot about them!

On guard
The guards were stationed in this room when on duty. They ate their meals here and warmed themselves near a basket of hot charcoal called a brazier.

CASTLE PERSONALITIES



Cesspool cleaner *Priest* *Noble family* *Jester* *Knight*



The keep
The keep was the strongest and largest tower in the castle. In it were the private rooms of the noble family as well as the great hall. The great hall was the center of castle society. It was the place where everyone gathered to eat and to watch entertainers such as musicians and jugglers.

Rub-a-dub-dub
During a siege, water was precious. Only the noble family bathed often.

Bailiff's room
In this room an official called the bailiff ran the lord's estates and counted and stored his treasure.

Solar comfort
A castle was a home as well as a fortress, so there were private rooms for the noble family. The solar was a private drawing room that may also have been used as a bedroom. It was usually the best room in the castle, with comfortable furnishings and a large window.

Private worship
The noble family worshiped in a chapel.

Chimneys
The oldest castles were very smoky, because smoke from fires could escape only through a hole in the roof. Chimneys, which worked better, were introduced in the 14th century.

A walk on the wall
Along the top of the castle wall was a path called a wall walk. It enabled defending soldiers to move quickly around the castle to the point of attack. Stone pillars, or battlements, protected soldiers on the wall walk from enemy arrows.

Cistern
Rainwater from the roofs drained into huge stone tanks called cisterns. Lead pipes took the water to the kitchen.

Wooden shutter
Window glass was not widely used until the 15th century; until then castles were very cold.

Deadly tubes
Soldiers used cannons (heavy guns) from the mid-14th century on. The first cannons were just tubes of metal fixed to stout wooden frames.

Cheers!
The beer in a 14th-century castle was very strong — even the "small beer" that children drank was more alcoholic than beer is today. It was brewed often, because 14th-century beer did not keep very well.

Splash!
The toilets in castles were called garderobes. They were very primitive. Usually there was just a hole that led to the outside wall. Sewage from some of the garderobes went straight into the moat.

Forging links
At the forge the armorer manufactured and repaired weapons and armor, and the farrier (blacksmith) made and fitted horseshoes.

Clever defense
Steps on the staircase always rose clockwise. This gave the defending soldier an advantage as he moved up or down: holding his sword in his right hand, he could swing it freely. But the center post blocked the attacker's sword hand.

Well, well...
Every castle needed lots of fresh water, so there was a deep well full of fresh water.

Open hearth
There was no stove in the kitchen. The cooks roasted meat in front of an open fire and boiled food in huge pots.

Food storage
To survive a siege, the castle inhabitants needed lots of food. Stores included hundreds of sacks of grain, which was made into flour for bread. The coolest part of the castle was the cellar, so perishable food was stored there.

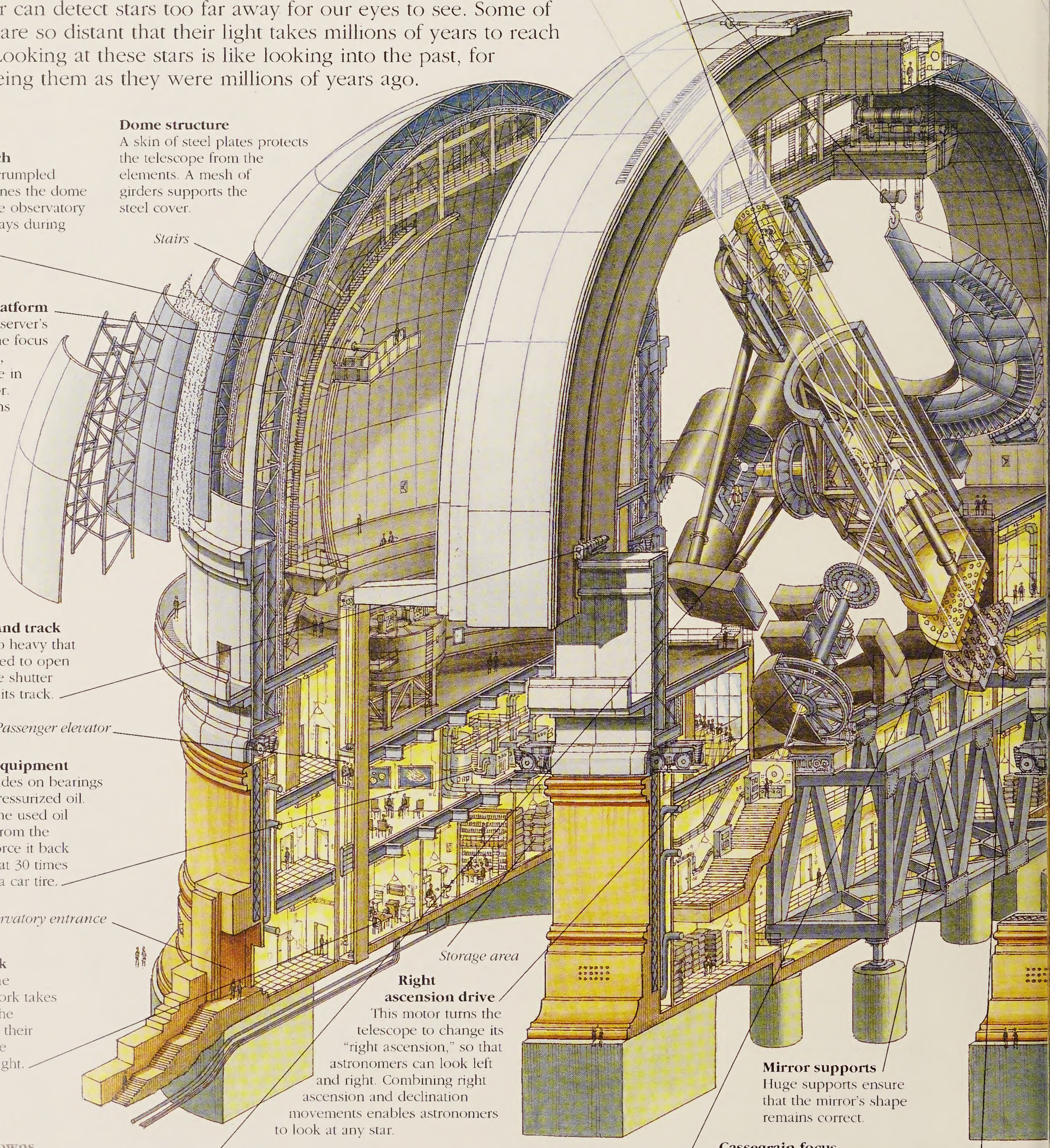
Salt meat
Meat was salted to preserve it.

This job's the pits...
Other garderobes in many parts of the castle emptied into pits called cesspools. Cleaning them out was a very smelly job!

Solid foundations
The castle walls were thickest at the bottom, where they were most at risk from tunneling by enemy miners. Only the shell of the castle wall was made from trimmed stones. Rubble filled the core of the castle wall.

OBSERVATORY

Through an ordinary high-powered telescope you can see mountains on the moon, nearly 240,000 miles away. The Hale telescope, however, at Mount Palomar, near San Diego, California, is so powerful that it is never pointed at anything as close as the moon. Instead, astronomers (people who study the stars) use it to look at more distant objects in the night sky. The telescope's 200-inch-wide mirror can detect stars too far away for our eyes to see. Some of these stars are so distant that their light takes millions of years to reach the earth. Looking at these stars is like looking into the past, for you are seeing them as they were millions of years ago.



Secondary mirrors
To focus the image from the primary mirror at points on the tube other than the prime focus, mirrors are swung into position below the observer's cage.

Crane
From time to time parts of the telescope must be removed for servicing; this is done with the help of a 67-ton overhead crane.

Dome structure
A skin of steel plates protects the telescope from the elements. A mesh of girders supports the steel cover.

Dome sandwich
A sandwich of crumpled aluminum foil lines the dome and insulates the observatory from the sun's rays during the day.

Prime focus platform
To reach the observer's cage at the prime focus of the telescope, astronomers ride in an open elevator. The elevator runs on curved rails and takes astronomers to within a step of the cage, regardless of the telescope's position.

Shutter drive and track
The shutter is so heavy that a motor is needed to open it by moving the shutter sideways along its track.

Oil-pumping equipment
The telescope rides on bearings supported by pressurized oil. Pumps collect the used oil where it flows from the bearings, and force it back to the bearings at 30 times the pressure in a car tire.

Midnight snack
Since most of the observatory's work takes place at night, the astronomers eat their main meal in the middle of the night.

Right ascension drive
This motor turns the telescope to change its "right ascension," so that astronomers can look left and right. Combining right ascension and declination movements enables astronomers to look at any star.

Mirror supports
Huge supports ensure that the mirror's shape remains correct.

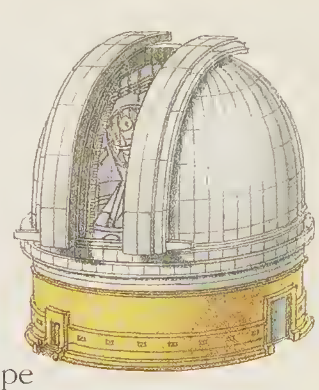
The ups and downs
To look at objects higher and lower in the sky, the telescope tilts up and down. Astronomers call the degree of tilt the declination. This huge gear wheel controls the up-and-down movement.

Marvelous mirror
A huge dish-shaped piece of special glass forms the primary or main mirror of the telescope. It weighs nearly 16.5 tons. The primary mirror is not a solid block: if it had been solid, cooling it after casting would have taken a year.

Cassegrain focus
Reflected light passes back through the primary mirror and forms an image at the "Cassegrain focus." This is the most used observing position. Images are recorded by devices similar to video camcorders.

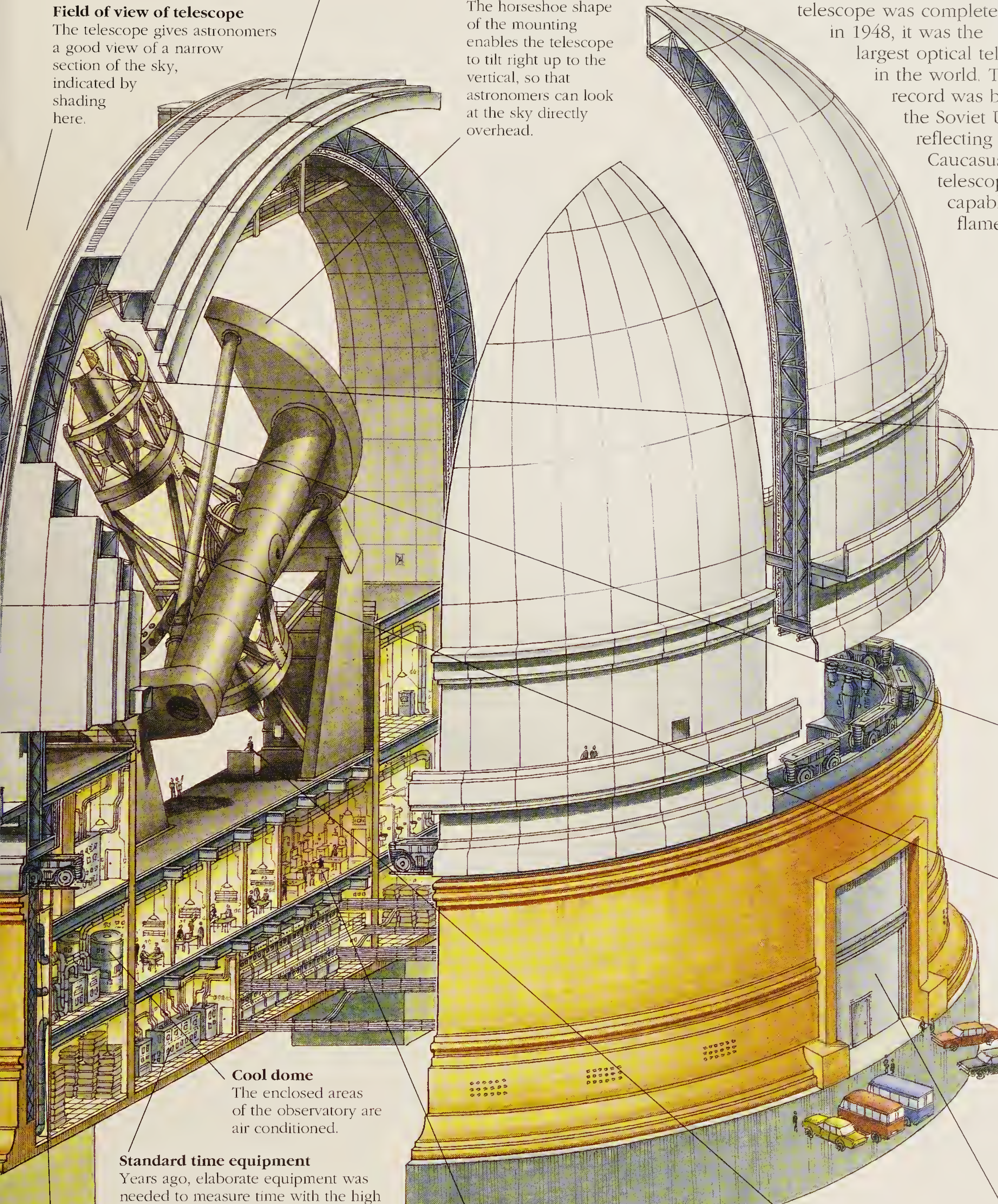
BIG EYES ON THE SKIES

The 200-inch reflecting telescope at Mount Palomar, in southern California, is named after George Ellery Hale (1868–1938), an American astronomer who helped plan and raise funds for the observatory. When the telescope was completed in 1948, it was the largest optical telescope in the world. The Hale telescope's size record was broken only in 1976, when the Soviet Union brought a 20-foot reflecting telescope into use in the Caucasus region. This vast telescope is so sensitive that it is capable of spotting a candle flame 14,000 miles away.



KEY FACTS

Dome diameter	135 feet
Mirror diameter	200 inches
Tube length	55 feet
Tube weight	594 tons



Dome shutter
The telescope "looks out" through a 30-foot-wide slot in the dome. When the observatory is not in use, a vast shutter covers the slot.

Shiny dome
Silver paint on the outside of the dome reflects the sun's heat, to help the observatory stay cool.

Field of view of telescope
The telescope gives astronomers a good view of a narrow section of the sky, indicated by shading here.

Mounting
The horseshoe shape of the mounting enables the telescope to tilt right up to the vertical, so that astronomers can look at the sky directly overhead.

Pressure bearings
The oil-pressured bearings reduce friction so much that even a strong gust of wind can turn the 550-ton weight of the telescope on its mounting.

Observer's cage
In most reflecting telescopes, the observer sees the image from the primary mirror by viewing its reflection in angled mirrors positioned inside the tube. The Hale telescope is so big, however, that the astronomer can actually sit inside the tube. This position is called the prime (main) focus, because the primary mirror gathers light from the sky and focuses it (projects a clear image) here.

Radial knife edges
Girders called knife edges support the observer's cage, but they are very thin so that they stop as little light as possible from reaching the primary mirror.

Telescope cage
To keep the mirrors the correct distance apart, the Hale telescope has steel beams arranged into a long cage weighing 600 tons. If the cage were completely rigid, it would be impossibly heavy. So the cage is slightly flexible — but it is constructed so that the optical components remain in correct alignment even when the cage flexes slightly under its own weight.

Cool dome
The enclosed areas of the observatory are air conditioned.

Standard time equipment
Years ago, elaborate equipment was needed to measure time with the high degree of precision that astronomers demand. Today, computerized timekeeping equipment is used and takes up much less space.

Equipment entrance
The observatory has an enormous door to provide access for heavy equipment.

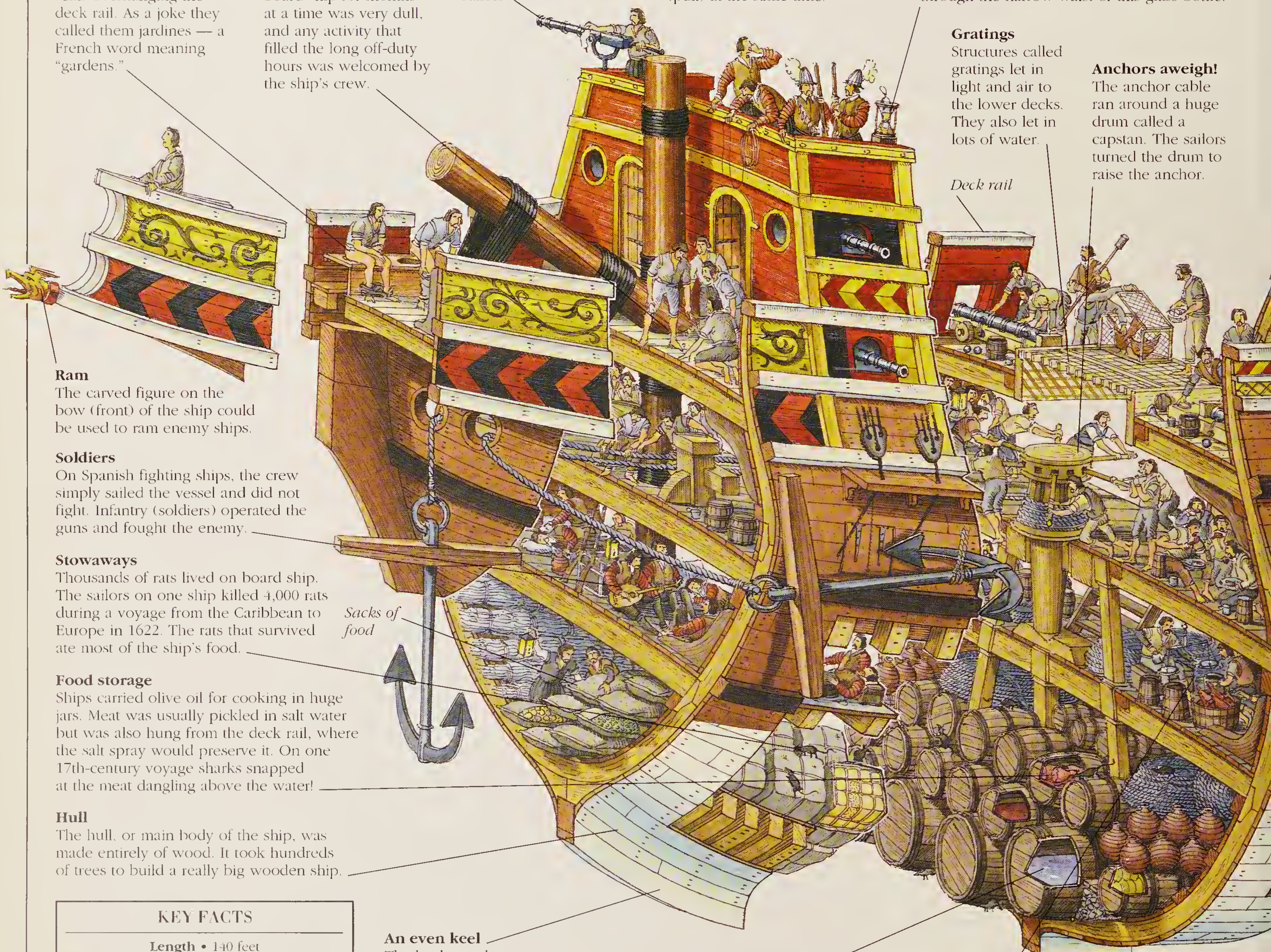
Dome wall
The dome of the telescope weighs more than 1,100 tons. It rests on wheeled trucks that run on rails around the edge of the observatory. Computer-controlled motors turn the dome to keep its opening aligned with the telescope.

Space snaps
The large darkroom dates from the time when astronomers used photographic plates to record their observations. Nowadays most observations are recorded electronically.

Dial-a-star
Astronomers can dial in the position of star they want to look at, and the telescope moves automatically into position.

GALLEON

In the 16th century, large ships regularly traveled back and forth across the Atlantic Ocean between Spain and its colonies in the New World. With their billowing sails and creaking timbers, these galleons looked and sounded beautiful. But what would it have been like for the sailors? The first thing they would have noticed when they went on board was the smell — a mixture of tar, sewage, and sweat. With a daily water ration of little more than one quart, there was not much left for washing. The ship was very crowded; there was no privacy, because every bit of space was needed for food and equipment. Huge rats scuttled in the shadows, and the ship was infested with fleas. The food tasted disgusting, and most of the crew members were constantly seasick. With a good wind, the journey from the Americas to Spain took more than two months. If the ship was becalmed (reached a patch of sea with no wind) or ran into rough weather, the journey could take even longer.



Jardines
For toilets, the crew used seats overhanging the deck rail. As a joke they called them jardines — a French word meaning "gardens."

Place your bets
Many sailors gambled, betting on cards, dice, and anything else that involved chance. Life on board ship for months at a time was very dull, and any activity that filled the long off-duty hours was welcomed by the ship's crew.

Swivel guns
These small guns were nicknamed "murderers." They were used against enemy sailors.

Tunes
The sailors sang special work songs called shanties. The songs had a strong rhythm which helped all the sailors to heave (pull) at the same time.

It's about time
Everyone in the crew took turns at the watch (keeping lookout). Watches lasted eight hours and were timed with an hourglass. Sand took half an hour to run through the narrow waist of this glass bottle.

Gratings
Structures called gratings let in light and air to the lower decks. They also let in lots of water.

Anchors aweigh!
The anchor cable ran around a huge drum called a capstan. The sailors turned the drum to raise the anchor.

Ram
The carved figure on the bow (front) of the ship could be used to ram enemy ships.

Soldiers
On Spanish fighting ships, the crew simply sailed the vessel and did not fight. Infantry (soldiers) operated the guns and fought the enemy.

Stowaways
Thousands of rats lived on board ship. The sailors on one ship killed 4,000 rats during a voyage from the Caribbean to Europe in 1622. The rats that survived ate most of the ship's food.

Food storage
Ships carried olive oil for cooking in huge jars. Meat was usually pickled in salt water but was also hung from the deck rail, where the salt spray would preserve it. On one 17th-century voyage sharks snapped at the meat dangling above the water!

Hull
The hull, or main body of the ship, was made entirely of wood. It took hundreds of trees to build a really big wooden ship.

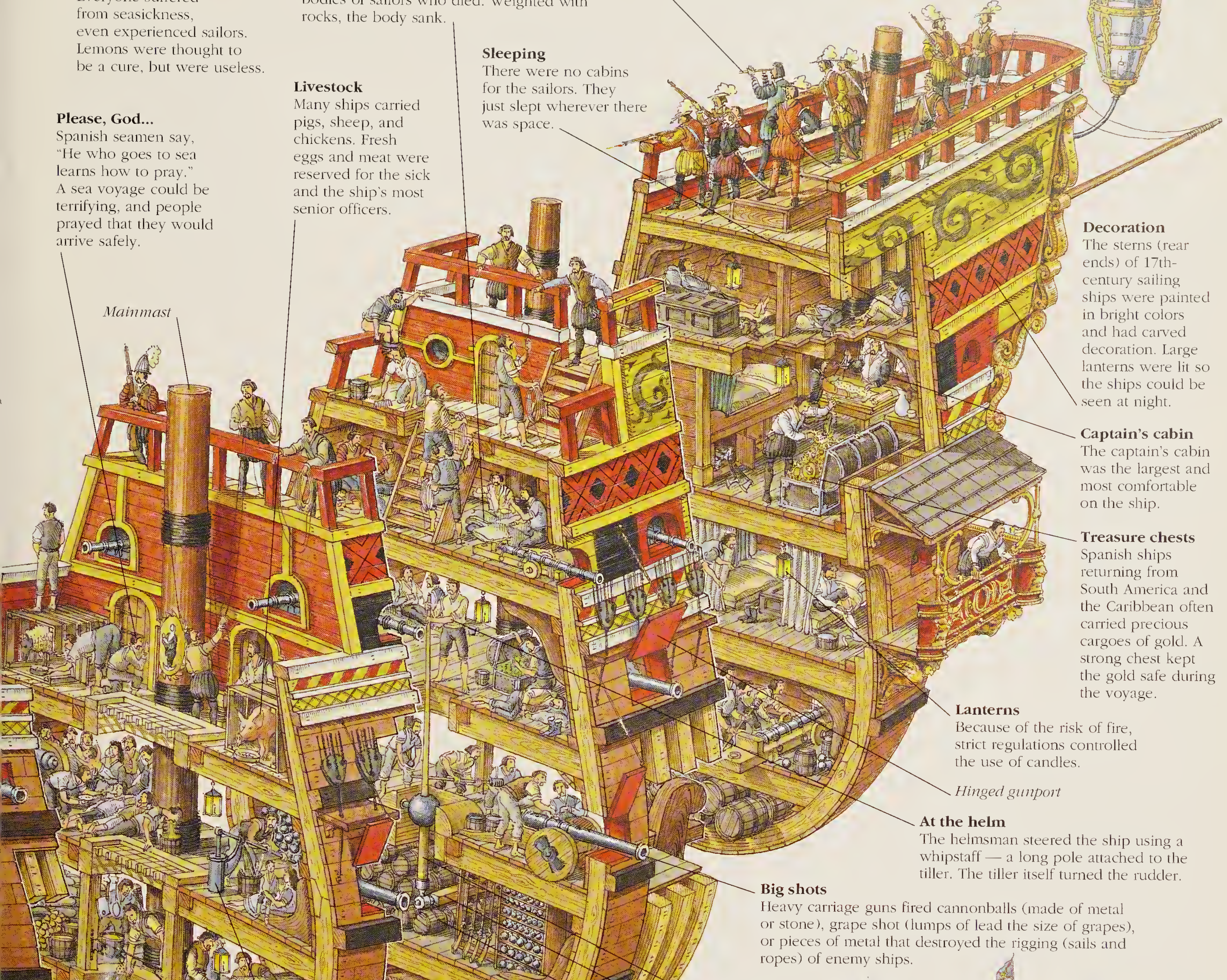
KEY FACTS

Length	140 feet
Keel length	98 feet
Beam (width)	36 feet
Weight	550 tons
Armament	24 cannon firing 31-pound balls, 30 cannon firing 18-pound balls, 2 swivel guns

An even keel
The keel was the backbone of the ship, and enabled it to sail in a straight line. To stay upright, the ship carried ballast in the hold (storage area). Rocks and cannonballs made good ballast.

Water, water everywhere...
Everyone on board was allowed only one quart of water each day, or twice this amount of beer or cider. Every ship had to carry enough fresh water for the whole voyage, because sea water contains too much dissolved salt to drink.

Food and cooking
Each day every member of the crew ate only 25 ounces of biscuits and 9 ounces of dried meat or fish. Sometimes there was a dish of boiled beans or peas as well. By the end of a long voyage a lot of food had gone bad, and the biscuits were filled with insects. When the sea was too rough, cooking was impossible, so everyone ate cheese instead of meat.



Heave ho!
Everyone suffered from seasickness, even experienced sailors. Lemons were thought to be a cure, but were useless.

Sew what
When sails became torn the crew had to repair them by hand. Sails that were badly damaged were sometimes used for shrouds to wrap the bodies of sailors who died. Weighted with rocks, the body sank.

What's that?
The crew looked at distant objects with a telescope, which made the objects appear bigger.

Please, God...
Spanish seamen say, "He who goes to sea learns how to pray." A sea voyage could be terrifying, and people prayed that they would arrive safely.

Livestock
Many ships carried pigs, sheep, and chickens. Fresh eggs and meat were reserved for the sick and the ship's most senior officers.

Sleeping
There were no cabins for the sailors. They just slept wherever there was space.

Decoration
The sterns (rear ends) of 17th-century sailing ships were painted in bright colors and had carved decoration. Large lanterns were lit so the ships could be seen at night.

Captain's cabin
The captain's cabin was the largest and most comfortable on the ship.

Treasure chests
Spanish ships returning from South America and the Caribbean often carried precious cargoes of gold. A strong chest kept the gold safe during the voyage.

Lanterns
Because of the risk of fire, strict regulations controlled the use of candles.

At the helm
The helmsman steered the ship using a whipstaff — a long pole attached to the tiller. The tiller itself turned the rudder.

Big shots
Heavy carriage guns fired cannonballs (made of metal or stone), grape shot (lumps of lead the size of grapes), or pieces of metal that destroyed the rigging (sails and ropes) of enemy ships.

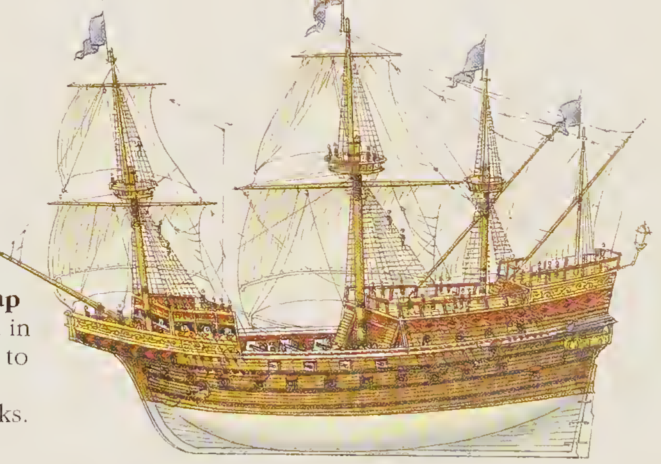
Watch the gap
Ropes soaked in tar were used to seal the gaps between planks.

Spares
Damage to the rigging was common, so every ship carried spares. Rats ate even the sails if they could, so spare sails were often stored in empty barrels.

The galley
Cooking facilities were different on every ship. Often there was no chimney, so the kitchen (called a galley on a ship) got very smoky.

A stinging sensation
Poisonous scorpions often lurked in the cargoes of wood that were carried in the hold.

Bilge brew
Sea water that seeped into the ship collected in the bilge — the space between the hold and the keel — and turned into a foul brew. This pump cleared the bilges, but the smell of the water was disgusting.

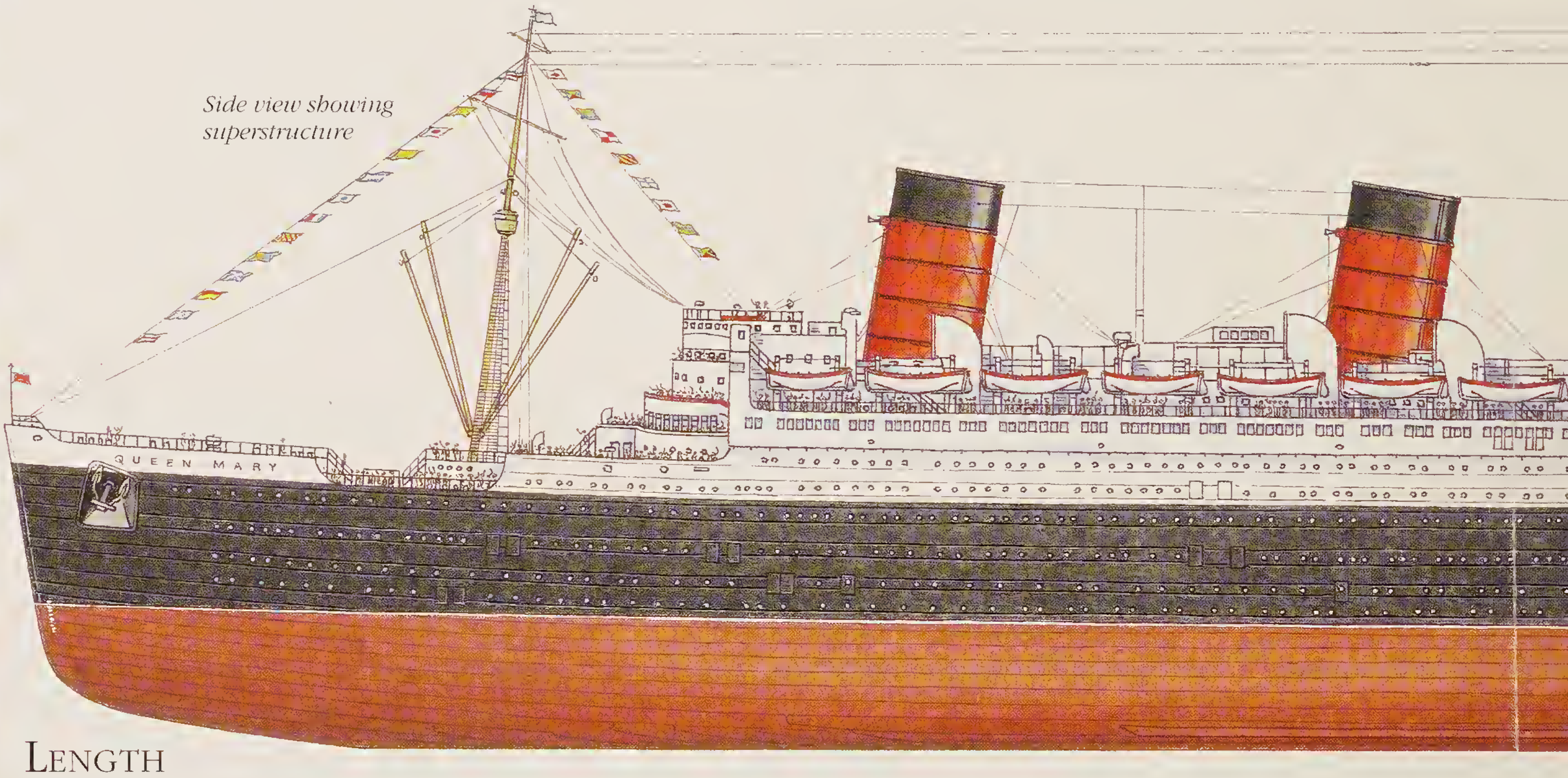


NEW HORIZONS

In the 16th century Spanish shipyards began to build a new kind of warship, called a galleon. It was based on an earlier design called a carrack but was narrower and more maneuverable. Naval guns had become powerful and accurate, and galleons were designed to use them most effectively.

OCEAN LINER

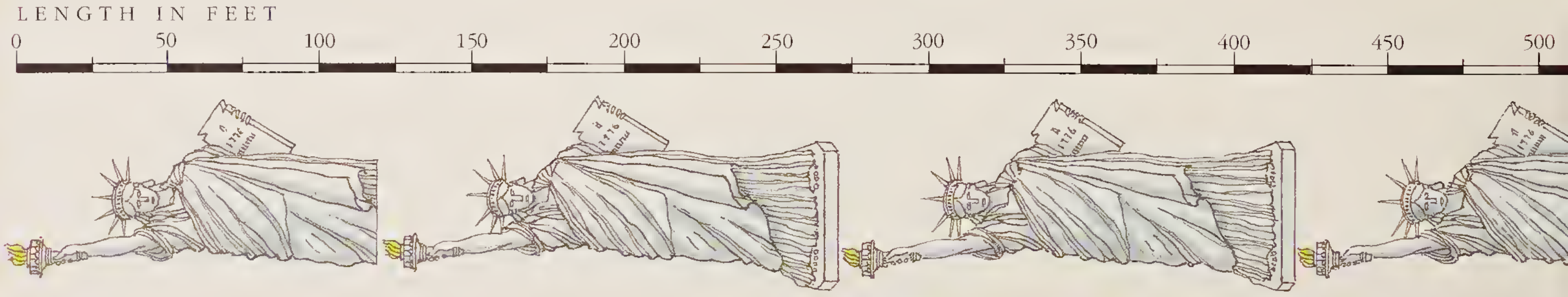
When ocean travel was fast and fashionable, the world's great shipping lines battled for business just as airlines do today. In a bid to be fastest across the Atlantic, Britain's Cunard Line built the *Queen Mary*, at that time the largest passenger liner in history. The prize for a fast liner was "The Blue Riband (ribbon) of the Atlantic." This wasn't actually a ribbon at all but an honorary title given to the ship that made the fastest crossing between the United States and Europe. The *Queen Mary* won the Blue Riband in August 1936 by crossing the ocean in just three minutes short of four days. A rival liner, the *Normandie*, regained the title the following year, but in August 1938 the *Queen Mary* took the honor once more, shaving two hours and 19 minutes off her previous record. The *Queen Mary* remained the fastest Atlantic passenger liner for 14 years.



Side view showing superstructure

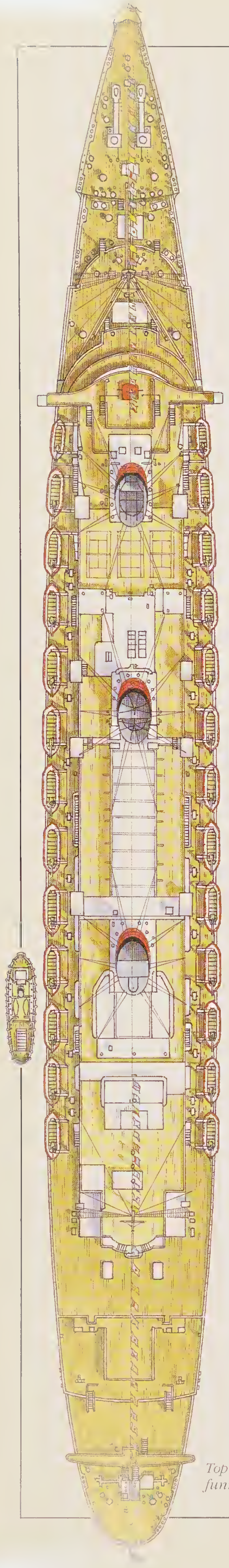
LENGTH

The size of the *Queen Mary* — longer than six Statues of Liberty — created vast problems for both the ship's builders and the New York port authorities. Before the ship could be built, an enormous dry dock had to be constructed in Britain. In New York, a special 1,000-foot pier was built.



GULL'S
EYE VIEW

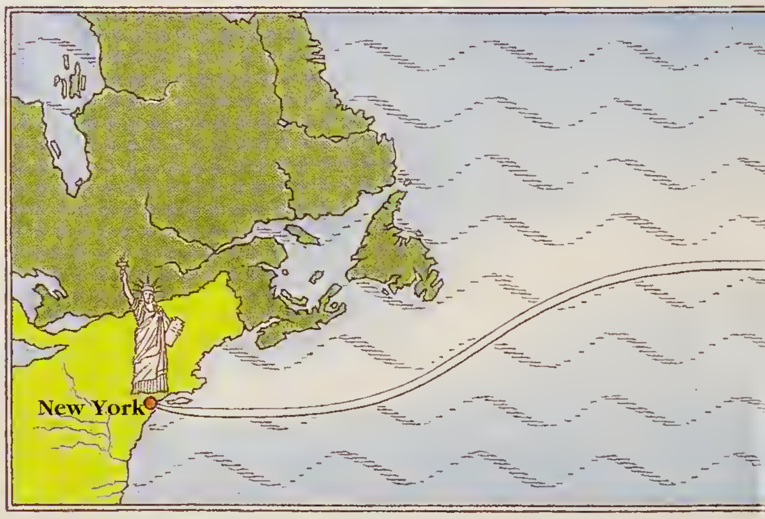
Seen from above, the tiny tennis courts give a sense of the enormous scale of the *Queen Mary's* decks. The lifeboats were rigged in constant readiness and were capable of carrying 145 people each. Fortunately, they never had to be used.



Top view showing funnels and decks

THE ROUTE

The *Queen Mary* sailed between New York and Southampton, on Britain's south coast. The liner's owners built the ship to run a weekly service between the two ports. To make the crossing in less than five days and beat the record of other shipping lines, the *Queen Mary* had to average 28.5 knots (32.8 mph).



OCEAN LINER

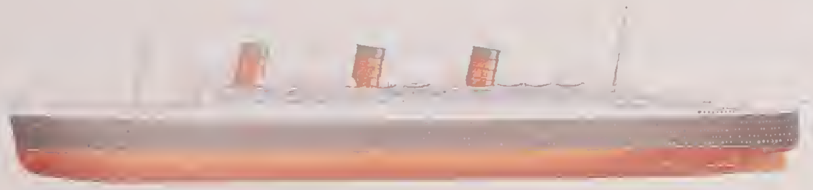
Crossing the Atlantic Ocean today in a supersonic airliner requires just a few hours of discomfort, but in 1936 things were different. Traveling between Britain and New York meant a sea voyage lasting at least four days — only the most daring flew.

Shipping companies of the time competed to provide passengers with the fastest, most luxurious crossing. It was this competition that led to the construction of the *Queen Mary*. When this enormous ship was built, she was the fastest passenger liner in the world, and probably the most luxurious. The ship's owner, the Cunard Line, spent millions to create a vast floating hotel as good as any found on land

The *Queen Mary* had three classes of passengers. Cabin-class (first-class) passengers had suites of rooms with fresh flowers, and adjoining cabins for their servants. Tourist-class (second-class) passengers had less lavish rooms, but they traveled in some style. Third-class passengers paid the least for their tickets and stayed in plainly furnished cabins in the noisiest, shakiest part of the ship.

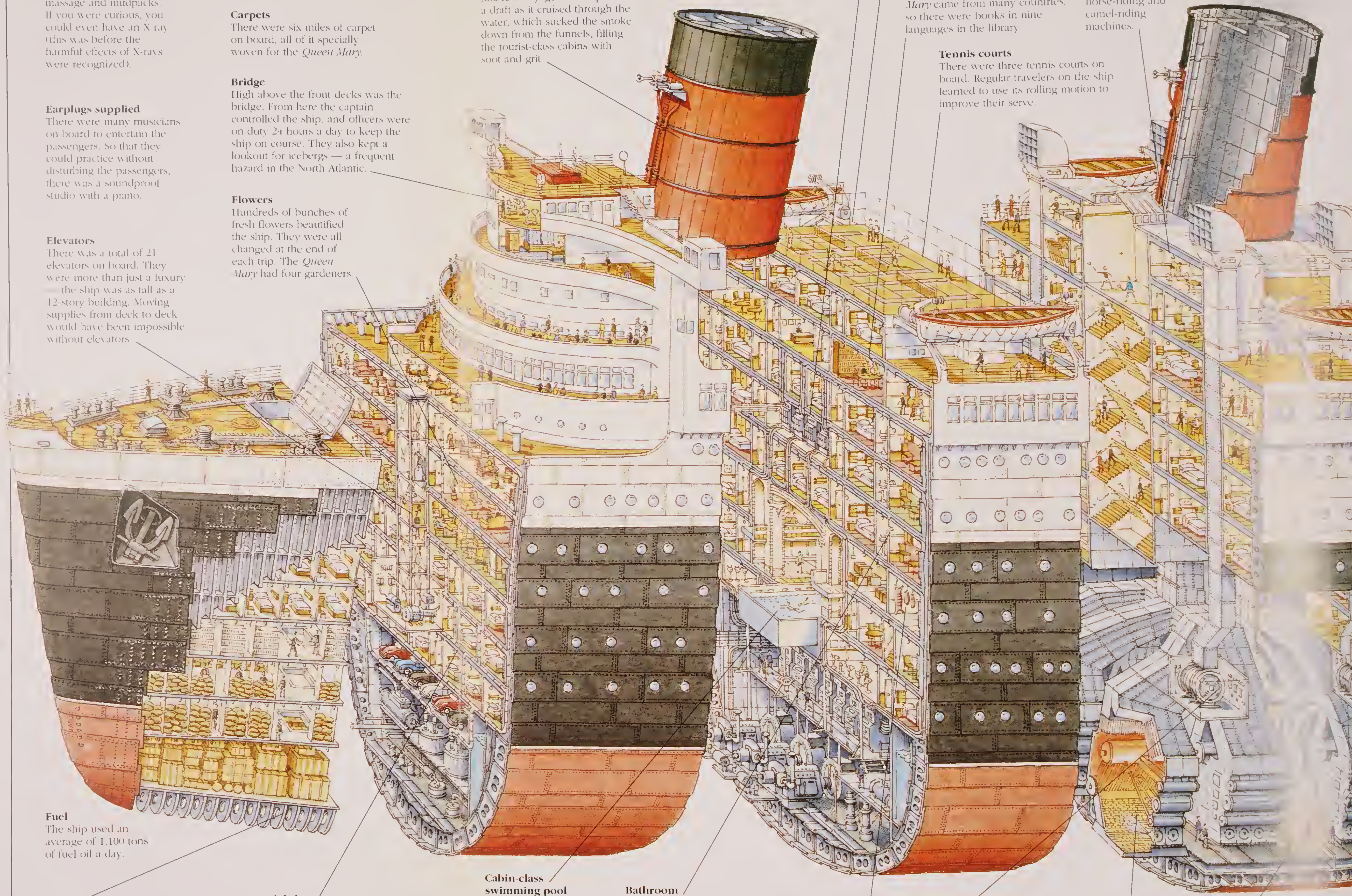
The Atlantic wind and waves, however, did not care how much each passenger had paid for a ticket. Those in cabin and third class suffered equally from seasickness. And how they suffered! Nobody had built a ship as big as the *Queen Mary* before, and her designers had no idea how much the Atlantic waves would toss and roll the ship. In the worst seas, the *Queen Mary* rolled 44 degrees. Everything that was not fixed to the floor rolled too. On the liner's maiden voyage, a piano broke free of its supports and crashed from side to side. It smashed against the costly furniture and paneling, emitting eerie twangs. At the end of the trip, all that remained unbroken in the room was the piano's steel frame and some of its strings.

The ship's owners acted quickly. With the aid of carefully positioned ballast (balancing weights) they made sure that the *Queen Mary* cut more smoothly through the waves. Soon the world's rich and famous were lining up to buy tickets.



NAMING A QUEEN?

There are many stories about the *Queen Mary*, some true and some untrue. One of the untrue stories is that Cunard originally wanted to name its new liner the *Queen Victoria*. When the company approached King George V for his permission, it said that the new ship was to be named after the greatest queen in English history. The king said that his wife would be delighted. His wife, of course, was Queen Mary.



Hairdressing and beauty parlors
These offered every service that you might expect in a beauty salon on land, including Vibro face massage and mudpacks. If you were curious, you could even have an X-ray (this was before the harmful effects of X-rays were recognized).

Earplugs supplied
There were many musicians on board to entertain the passengers. So that they could practice without disturbing the passengers, there was a soundproof studio with a piano.

Elevators
There was a total of 21 elevators on board. They were more than just a luxury — the ship was as tall as a 12-story building. Moving supplies from deck to deck would have been impossible without elevators

Kennels
Dogs were luxuriously accommodated in 26 kennels. They even had their own 80-foot exercise area—and a lamppost.

Carpets
There were six miles of carpet on board, all of it specially woven for the *Queen Mary*.

Bridge
High above the front decks was the bridge. From here the captain controlled the ship, and officers were on duty 24 hours a day to keep the ship on course. They also kept a lookout for icebergs — a frequent hazard in the North Atlantic.

Flowers
Hundreds of bunches of fresh flowers beautified the ship. They were all changed at the end of each trip. The *Queen Mary* had four gardeners.

Funnels
Smoke and steam from the boilers rose through three funnels (chimneys). Each was big enough to hold three double-decker buses side by side. Unfortunately, on its first few voyages the ship created a draft as it cruised through the water, which sucked the smoke down from the funnels, filling the tourist-class cabins with soot and grit.

Switchboard
To distribute power all over the ship, there were more than 50 switchboards.

Games deck
The games deck covered two acres — more than an entire football field.

Library
The passengers on the *Queen Mary* came from many countries, so there were books in nine languages in the library

Tennis courts
There were three tennis courts on board. Regular travelers on the ship learned to use its rolling motion to improve their serve.

Gymnasium
Passengers ate such a rich diet in the ship's restaurants that they needed to work out to keep off the flab. The gym catered to the most exotic tastes in exercise, and its equipment included horse-riding and camel-riding machines.

Fuel
The ship used an average of 1,100 tons of fuel oil a day.

Keel
The keel of the *Queen Mary* was made of huge plates 30 feet long and 6 feet high, joined by riveted straps. The hull was covered with steel plates about 1 inch thick, and was triple-riveted in some places.

Lighting
The 30,000 light bulbs on the ship required constant attention. A team of electricians spent half the night changing burned-out bulbs while the passengers slept.

Cabin-class swimming pool
The full-size swimming pool was very impressive in calm weather, but in rough seas it had to be drained, because the rolling of the ship created huge waves in the pool!

Bathroom
Until the 1950s passengers had to wash in seawater, using special soap (ordinary soap doesn't produce a lather in salty water). Later, though, a desalination plant extracted the salt so that everyone could have freshwater baths.

Food storage
The ship required enormous quantities of food for the passengers and crew. The galleys (kitchens) used 10 tons of flour, 27.5 tons of potatoes, and more than 75,000 eggs during a single voyage.

Forced-draft fan rooms
To make the boilers work more efficiently, enormous fans sucked air from vents on the upper decks and forced it into the boilers.

Boilers
Four steam turbines powered the liner through the waves. Each one generated 50,000 horsepower: as much as 400 family cars.

Boiler room
Besides the boilers for the engines, three boilers generated steam to supply electrical power and heating to the ship

Smoking room
To create the impression of a comfortable English country club, the smoking room had leather covered chairs and a coal fire.

Dummy funnel
Part of the *Queen Mary's* third funnel was a dummy — it was used to store deck chairs.

It's for you!
Passengers could telephone from the ship. Though we take this for granted today, it must have seemed amazing at a time when telephones in the home were a luxury.

Clock
[illegible] York time is five hours behind [illegible] time, so on the westward [illegible] the days were 25 hours [illegible] Eastward, they were only 23.

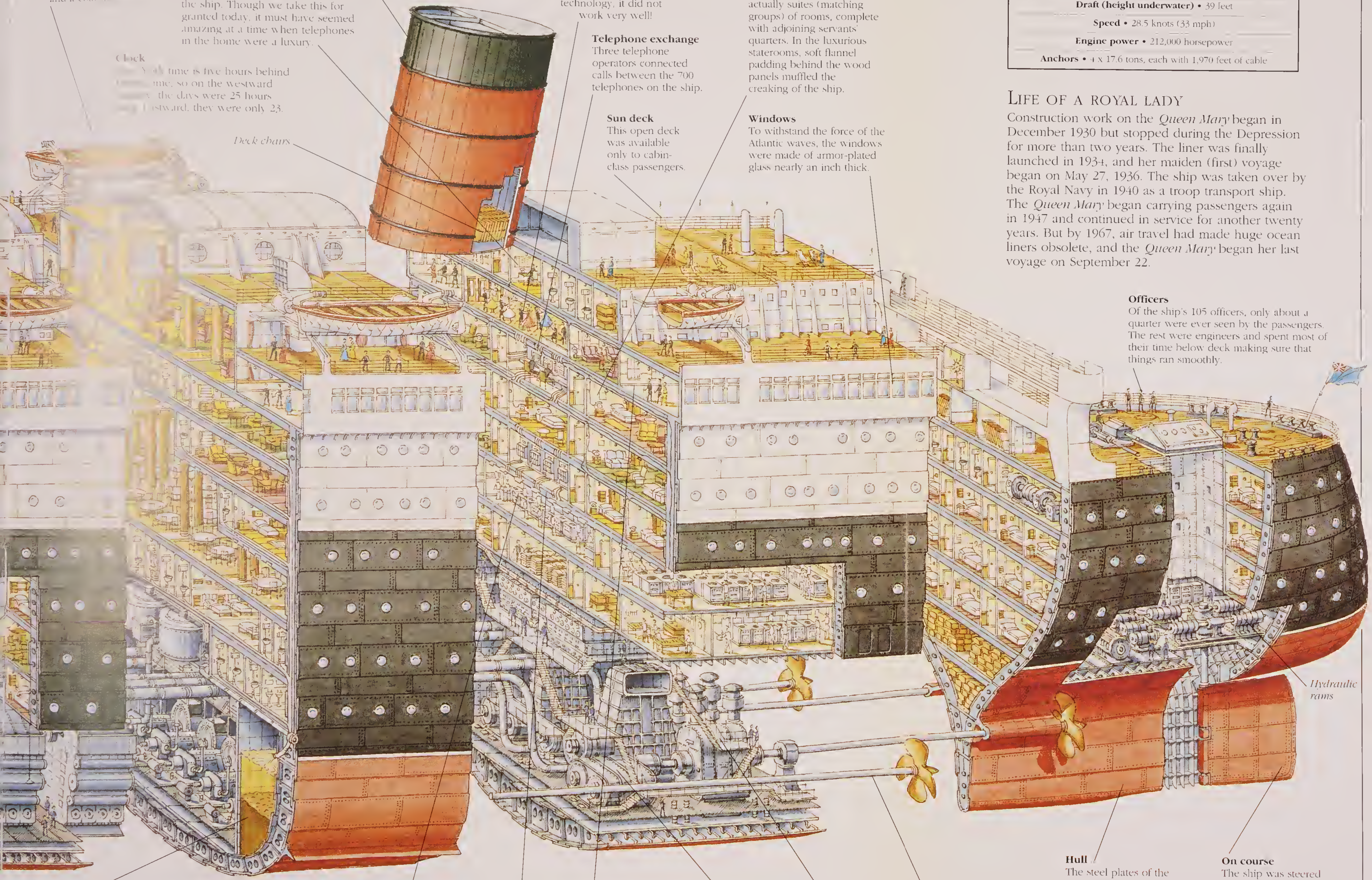
Veranda grill
Lights in this ballroom were controlled by a Thyratron, a device that dimmed the lights when the music was quiet and made them brighter when it was loud. The Thyratron was very advanced technology at the time. However, like much high technology, it did not work very well!

Telephone exchange
Three telephone operators connected calls between the 700 telephones on the ship.

Sun deck
This open deck was available only to cabin-class passengers.

Staterooms
The most expensive cabins were next to the promenade deck. The best of them were actually suites (matching groups) of rooms, complete with adjoining servants' quarters. In the luxurious staterooms, soft flannel padding behind the wood panels muffled the creaking of the ship.

Windows
To withstand the force of the Atlantic waves, the windows were made of armor-plated glass nearly an inch thick.



Officers
Of the ship's 105 officers, only about a quarter were ever seen by the passengers. The rest were engineers and spent most of their time below deck making sure that things ran smoothly.

Sewage
Waste from the liner's lavatories collected in sewage tanks along the side of the ship.

Galleys
The three galleys could prepare meals for 3,000 people at a time. They covered an area of one acre and catered to every type of diet. A bakery made fresh bread each day.

There were 16,000 pieces of cutlery, 200,000 pieces of crockery, and half a million pieces of table linen (tablecloths and napkins).

Send me a cable
There were 4,000 miles of electrical cable on board. The *Queen Mary* used electricity to power many devices that had been steam-operated on older ships.

Jogger's delight
Three times around the promenade deck was a one-mile walk.

Powerhouse
The seven generators produced enough power for a town of 9,000 people.

Gear box
The largest gear wheel in the gearbox was 14 feet across.

Propeller shaft
The engines drove huge propeller shafts, each as wide as a tree trunk.

Hull
The steel plates of the *Queen Mary's* hull were about an inch thick, and the hull was held together by more than 10 million rivets. Huge steel beams almost a foot thick held the ship together.

On course
The ship was steered by one of the biggest rudders in the world, turned by powerful hydraulic cylinders. The rudder was the size of a house and weighed as much as twenty 10-ton trucks.

KEY FACTS

Length • 1,020 feet
Length at the waterline • 1,004 feet
Beam (width) • 118 feet
Draft (height underwater) • 39 feet
Speed • 28.5 knots (33 mph)
Engine power • 212,000 horsepower
Anchors • 4 x 17.6 tons, each with 1,970 feet of cable

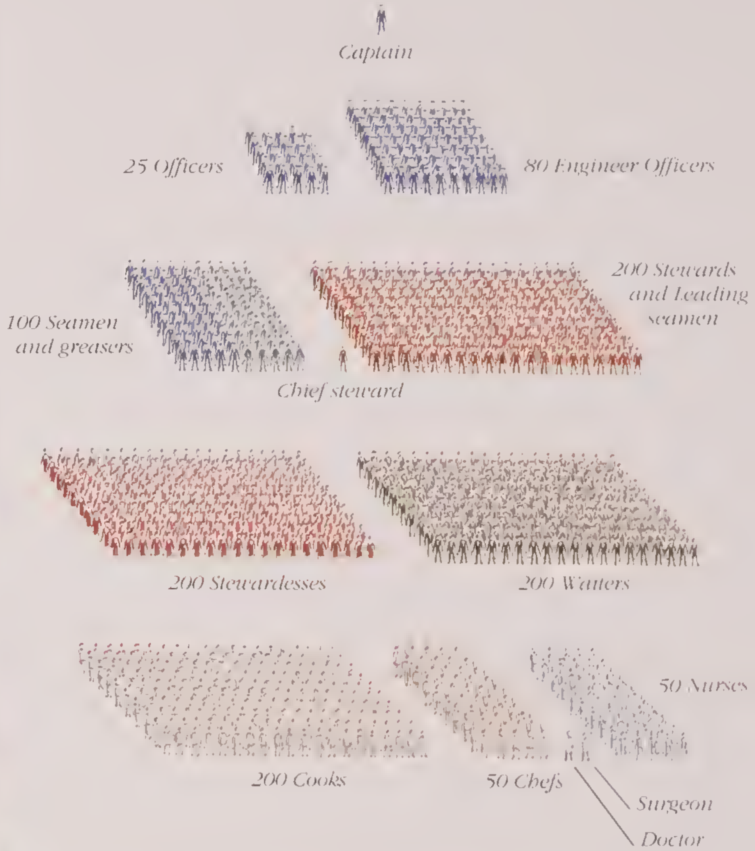
LIFE OF A ROYAL LADY

Construction work on the *Queen Mary* began in December 1930 but stopped during the Depression for more than two years. The liner was finally launched in 1934, and her maiden (first) voyage began on May 27, 1936. The ship was taken over by the Royal Navy in 1940 as a troop transport ship. The *Queen Mary* began carrying passengers again in 1947 and continued in service for another twenty years. But by 1967, air travel had made huge ocean liners obsolete, and the *Queen Mary* began her last voyage on September 22.

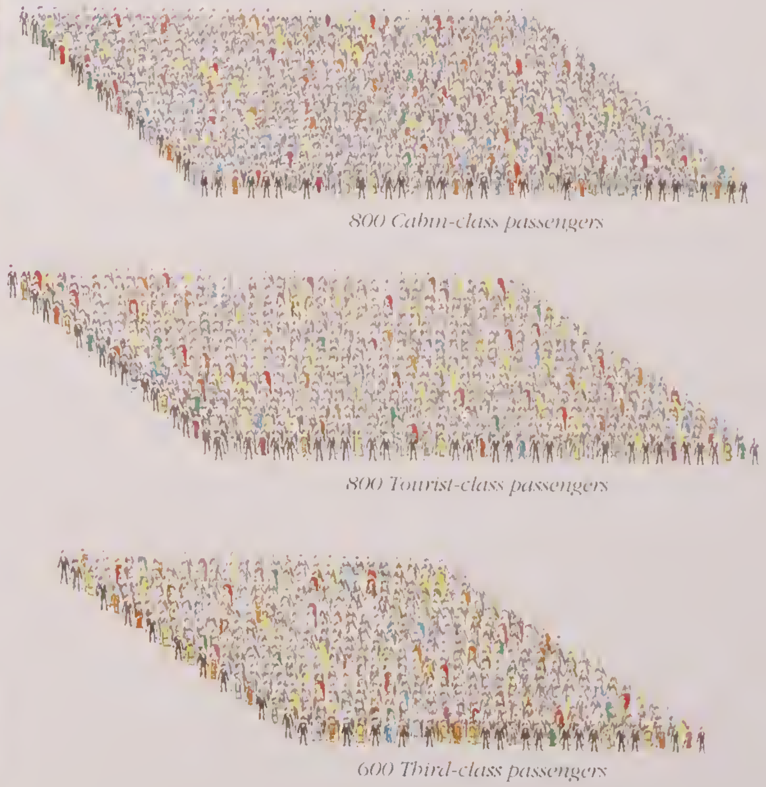
WHO WAS ON BOARD?

The *Queen Mary* could carry more than 2,000 passengers. To keep all of them happy, the ship's crew included bellboys, maids, nurses, and barmen — besides the engineers, quartermasters, stokers, and greasers needed simply to sail the ship.

THE CREW

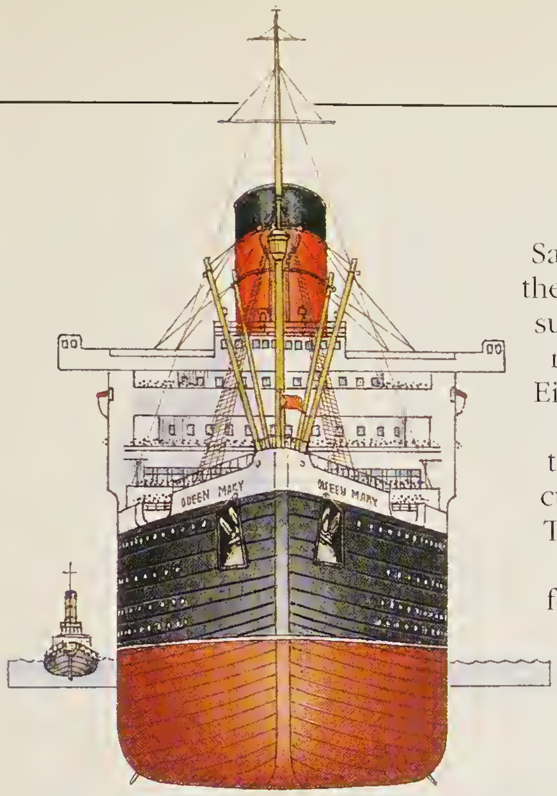


THE PASSENGERS

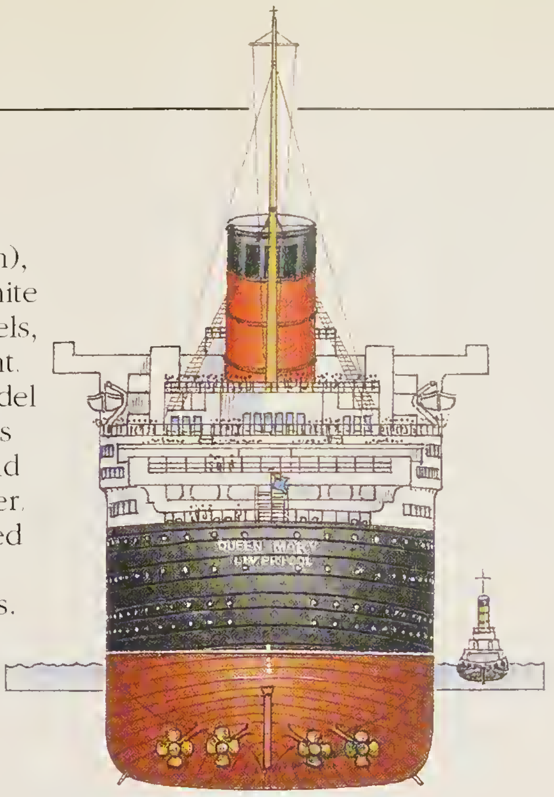


PROW AND PROPS

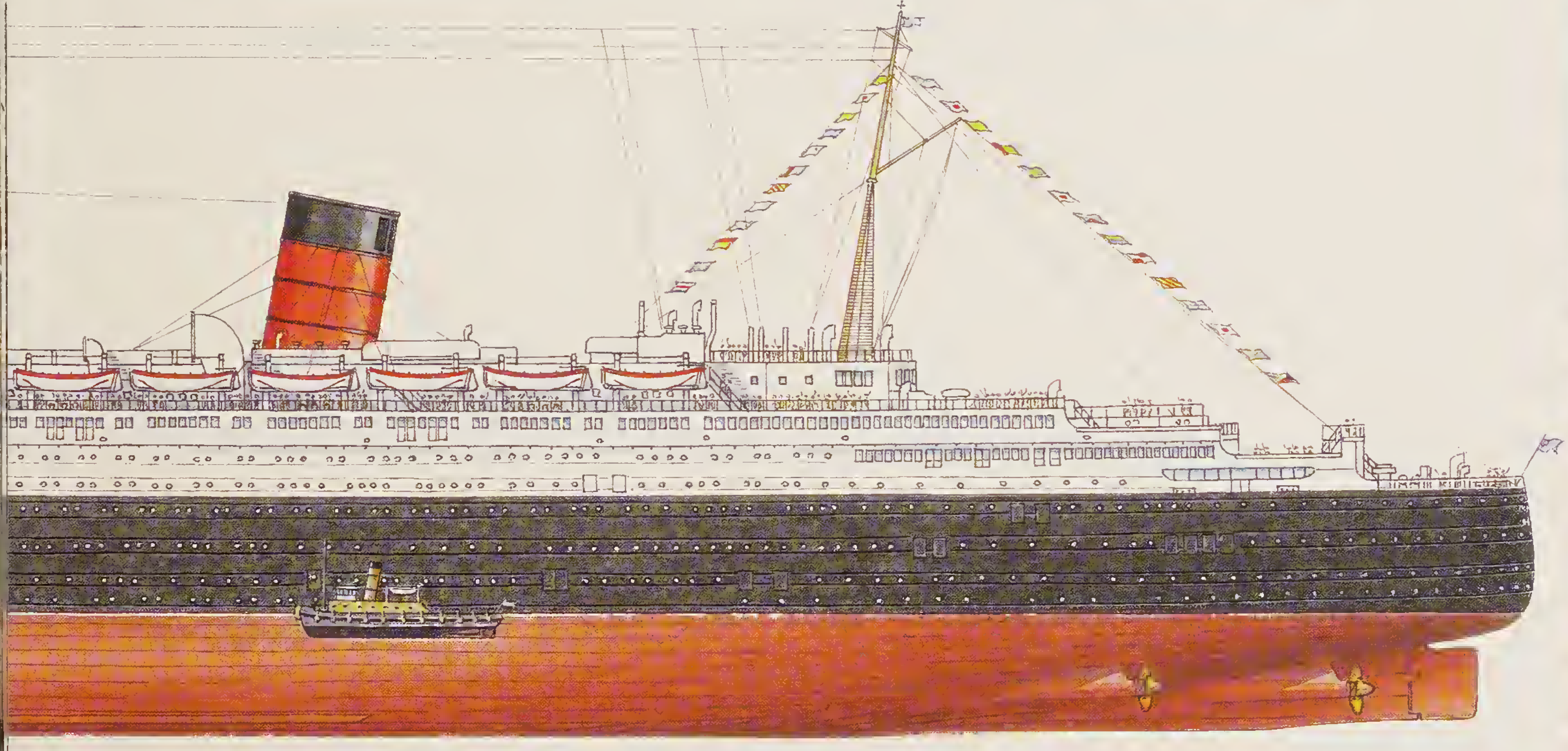
Sailing at 30 knots (34.5 mph), the *Queen Mary*, with her white superstructure and red funnels, made an awe-inspiring sight. Eighteen thousand scale-model tests ensured that the ship's towering prow (front) would cut cleanly through the water. The *Queen Mary* was pushed forward in the water by four 20-foot-wide propellers.



Bow view showing anchors and superstructure

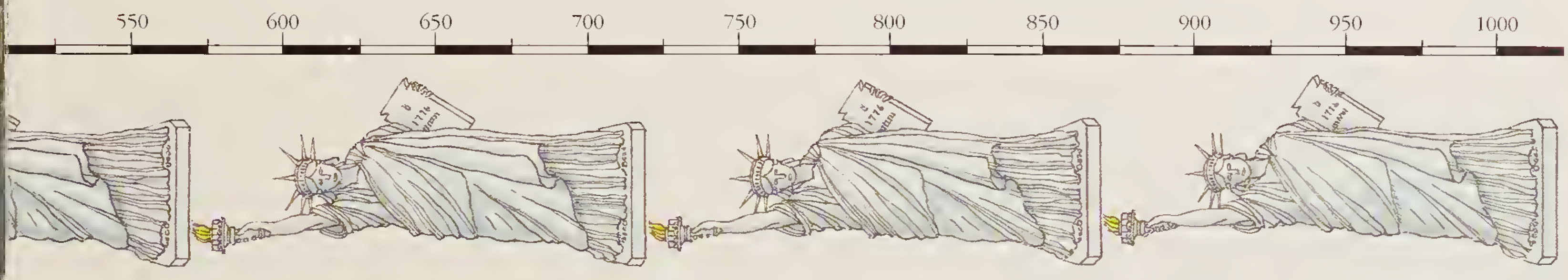


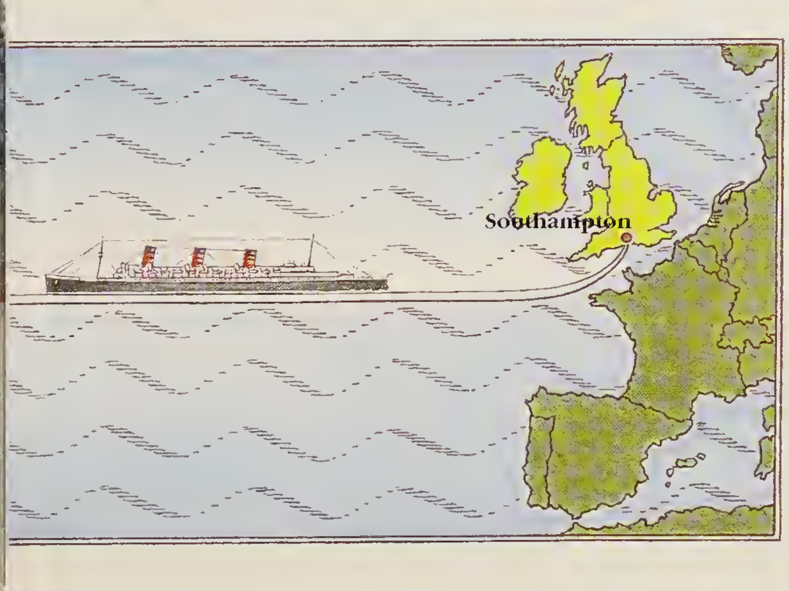
Stern view showing rudder and propellers



DECKS AND CABINS

Careful planning enforced a strict social class system on board ship. The height above the waterline indicated status: passengers who paid the most had airy views from the upper decks; the lowest-paid crew members had cabins without portholes below the waterline.



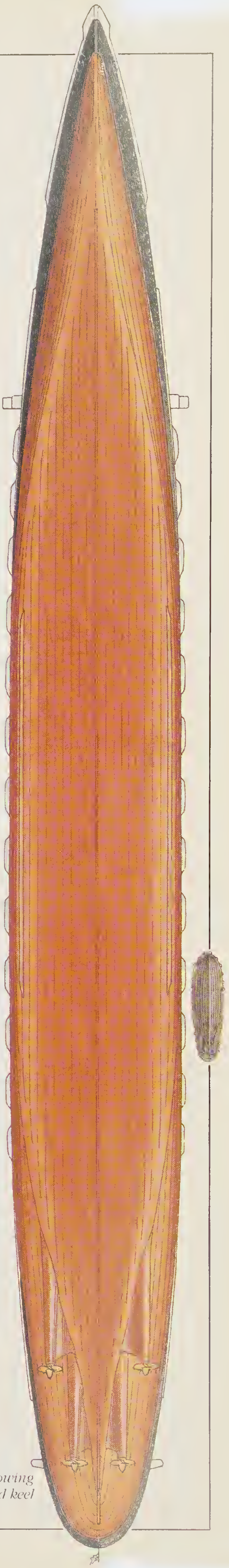


CUNARD

The Cunard Line was founded in 1839 by Samuel (later Sir Samuel) Cunard. Cunard started a transatlantic passenger service between Britain and the United States. Cunard's first ship was the *Britannia,* on which Charles Dickens, the British author, traveled to New York in 1842.

THE HULL

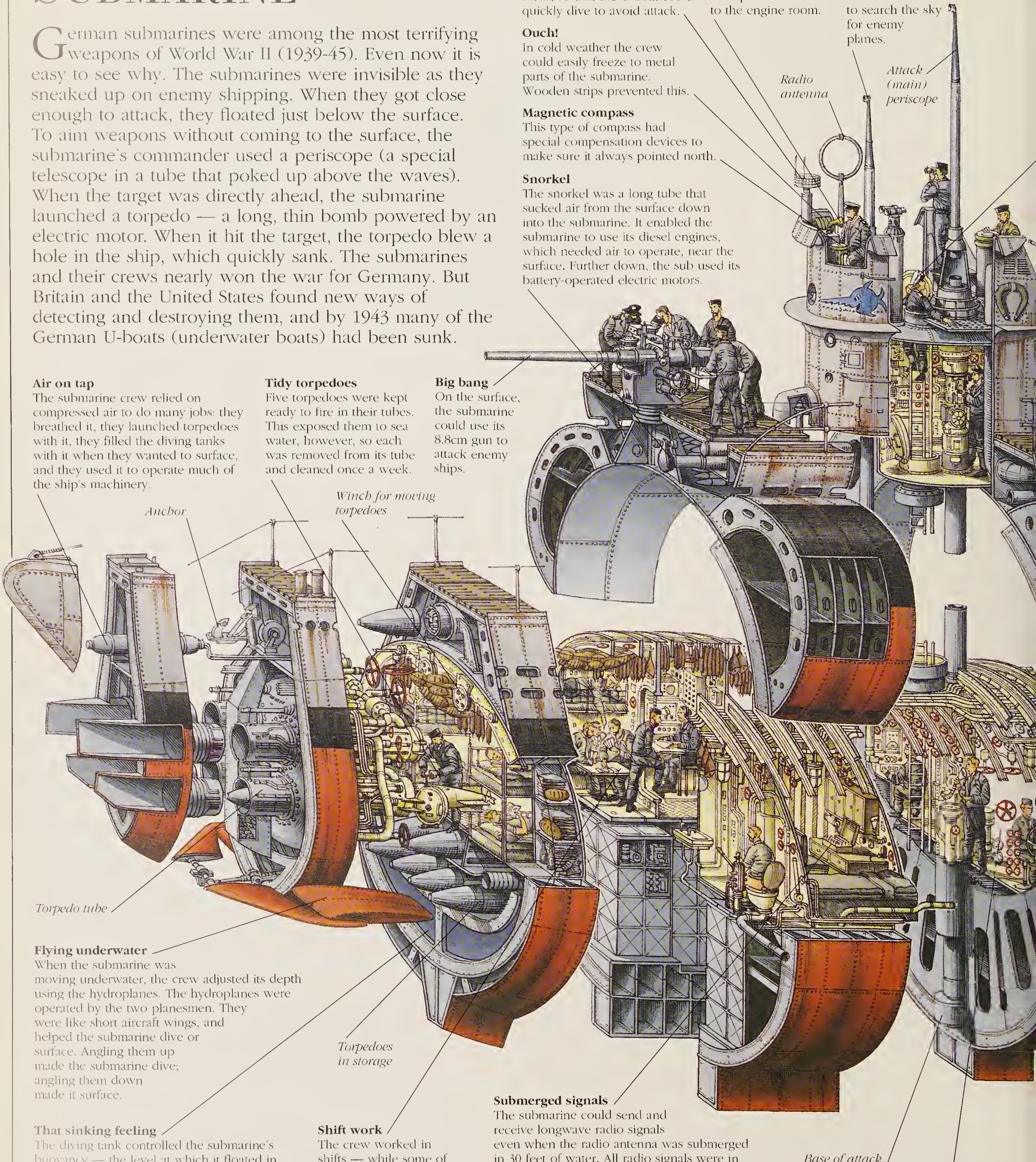
Ten million rivets held together the 160 watertight compartments that divided the vast hull. If the ship was holed, the water would fill only one compartment, and the ship would not sink. At the stern (rear) of the ship was the rudder, which was as big as a house and weighed 198 tons.



Bottom view showing propellers and keel

SUBMARINE

German submarines were among the most terrifying weapons of World War II (1939-45). Even now it is easy to see why. The submarines were invisible as they sneaked up on enemy shipping. When they got close enough to attack, they floated just below the surface. To aim weapons without coming to the surface, the submarine's commander used a periscope (a special telescope in a tube that poked up above the waves). When the target was directly ahead, the submarine launched a torpedo — a long, thin bomb powered by an electric motor. When it hit the target, the torpedo blew a hole in the ship, which quickly sank. The submarines and their crews nearly won the war for Germany. But Britain and the United States found new ways of detecting and destroying them, and by 1943 many of the German U-boats (underwater boats) had been sunk.



Radar antenna
This antenna detected aircraft radar, so that the U-boat could quickly dive to avoid attack.

Is anybody there?
The commander used a simple tube to talk to the engine room.

It's a bird...
A small periscope enabled the crew to search the sky for enemy planes.

Ouch!
In cold weather the crew could easily freeze to metal parts of the submarine. Wooden strips prevented this.

Magnetic compass
This type of compass had special compensation devices to make sure it always pointed north.

Snorkel
The snorkel was a long tube that sucked air from the surface down into the submarine. It enabled the submarine to use its diesel engines, which needed air to operate, near the surface. Further down, the sub used its battery-operated electric motors.

Air on tap
The submarine crew relied on compressed air to do many jobs: they breathed it, they launched torpedoes with it, they filled the diving tanks with it when they wanted to surface, and they used it to operate much of the ship's machinery.

Tidy torpedoes
Five torpedoes were kept ready to fire in their tubes. This exposed them to sea water, however, so each was removed from its tube and cleaned once a week.

Big bang
On the surface, the submarine could use its 8.8cm gun to attack enemy ships.

Flying underwater
When the submarine was moving underwater, the crew adjusted its depth using the hydroplanes. The hydroplanes were operated by the two planesmen. They were like short aircraft wings, and helped the submarine dive or surface. Angling them up made the submarine dive; angling them down made it surface.

That sinking feeling
The diving tank controlled the submarine's buoyancy — the level at which it floated in the water. When the submarine operated on the surface, the diving tanks were full of air. Releasing the air so that the tanks filled with water made the submarine dive deeper.

Shift work
The crew worked in shifts — while some of them worked, the rest slept. There were only enough beds for one shift to sleep in at a time.

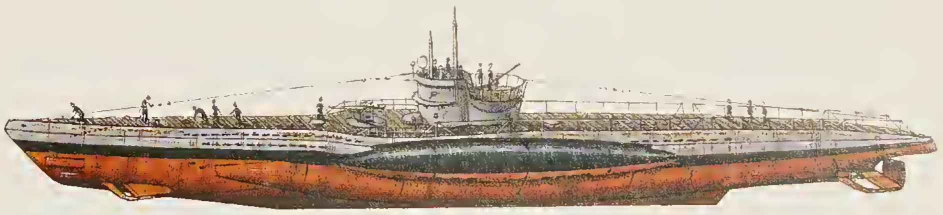
Submerged signals
The submarine could send and receive longwave radio signals even when the radio antenna was submerged in 30 feet of water. All radio signals were in code, so that the enemy could not understand the messages if they intercepted them. The captain used a machine to code outgoing messages and decode incoming ones.

Listen up!
German submarines experimented with an acoustic torpedo, which steered toward its target by "listening" for the ship's engines. Some of the first experiments with acoustic torpedoes were disasters — because the submarine's engines were louder than those of the target, the torpedo turned around and blew up the submarine!

Hatch
A powerful locking mechanism on the hatch kept water from leaking in when the submarine dived.

Conning tower
The raised structure in the center of the submarine was called the conning tower. The commander steered (or "conned") the submarine from here when the boat was running on the surface.

U-BOAT TYPE VII-C



The German navy put 650 type VII-C U-boats into service during World War II. This submarine was cheaper to build and smaller than the submarines of Germany's enemies, but it had sufficient range to be able to carry out missions far out into the Atlantic Ocean. Although it was out of date by the end of the war, the VII-C was an advanced and dangerous weapon when it first appeared.

KEY FACTS

Length • 221 feet

Maximum diameter • 20 feet

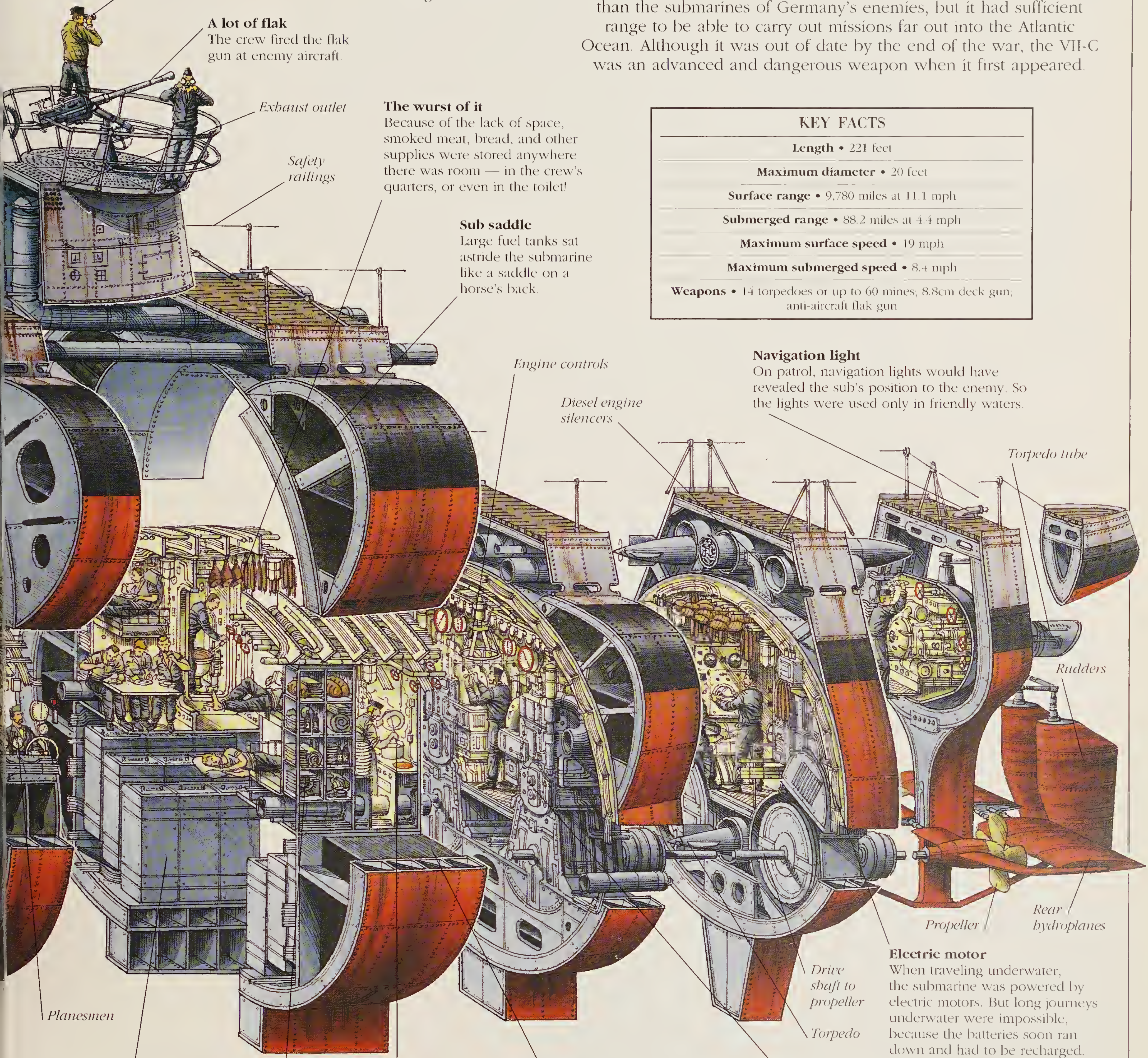
Surface range • 9,780 miles at 11.1 mph

Submerged range • 88.2 miles at 4.4 mph

Maximum surface speed • 19 mph

Maximum submerged speed • 8.4 mph

Weapons • 14 torpedoes or up to 60 mines; 8.8cm deck gun; anti-aircraft flak gun



A lot of flak
The crew fired the flak gun at enemy aircraft.

The wurst of it
Because of the lack of space, smoked meat, bread, and other supplies were stored anywhere there was room — in the crew's quarters, or even in the toilet!

Sub saddle
Large fuel tanks sat astride the submarine like a saddle on a horse's back.

Navigation light
On patrol, navigation lights would have revealed the sub's position to the enemy. So the lights were used only in friendly waters.

Big batteries
The submarine carried enormous batteries to power the electric motor. They stored enough electricity to power 1,000 lightbulbs for 24 hours.

Lockers
The crew's lockers were very small. One visitor described them as "the size of a briefcase."

Crude cooking
Cooking facilities were crude in the galley. The cook had just two hot plates.

Supply line
The amount of fuel the submarine could carry limited the range it could travel. To extend the range, the German navy built supply submarines — U-boats that carried only fuel and supplies.

Electric motor
When traveling underwater, the submarine was powered by electric motors. But long journeys underwater were impossible, because the batteries soon ran down and had to be recharged.

Diesel power
Powerful diesel engines propelled the submarine forward on or near the surface. They could not be used deep underwater, however, because they needed air to operate. Starting the diesel engines while submerged would have rapidly sucked all the air out of the submarine, suffocating the crew.

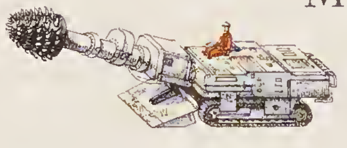
COAL MINE

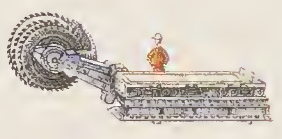
Inside a low tunnel two miles beneath our feet, coal miners operate machines that take great bites out of the earth's crust in order to extract coal from rock. In our bright homes above, many of us never see the coal dug out by the miners and their machines. Nevertheless we still use it: in many homes, electricity generated by burning coal powers lightbulbs and appliances every day.

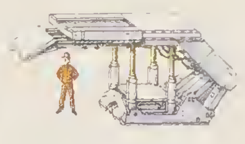
People began burning coal thousands of years ago. At first they used coal that they found on the surface of the ground, but they soon began to dig pits and shafts to find coal seams — layers of coal buried in the rocks underground. In these early mines, miners risked their lives every day to dig out the "black diamonds" using pickaxes, shovels, and, later, explosives. Today's miners are helped by computers and giant machines, but mines are still dark, damp, dirty, and dangerous places.

Pithead
Most of the mine is below ground, but work also takes place on the surface. The offices and workshops above ground are called the pithead.

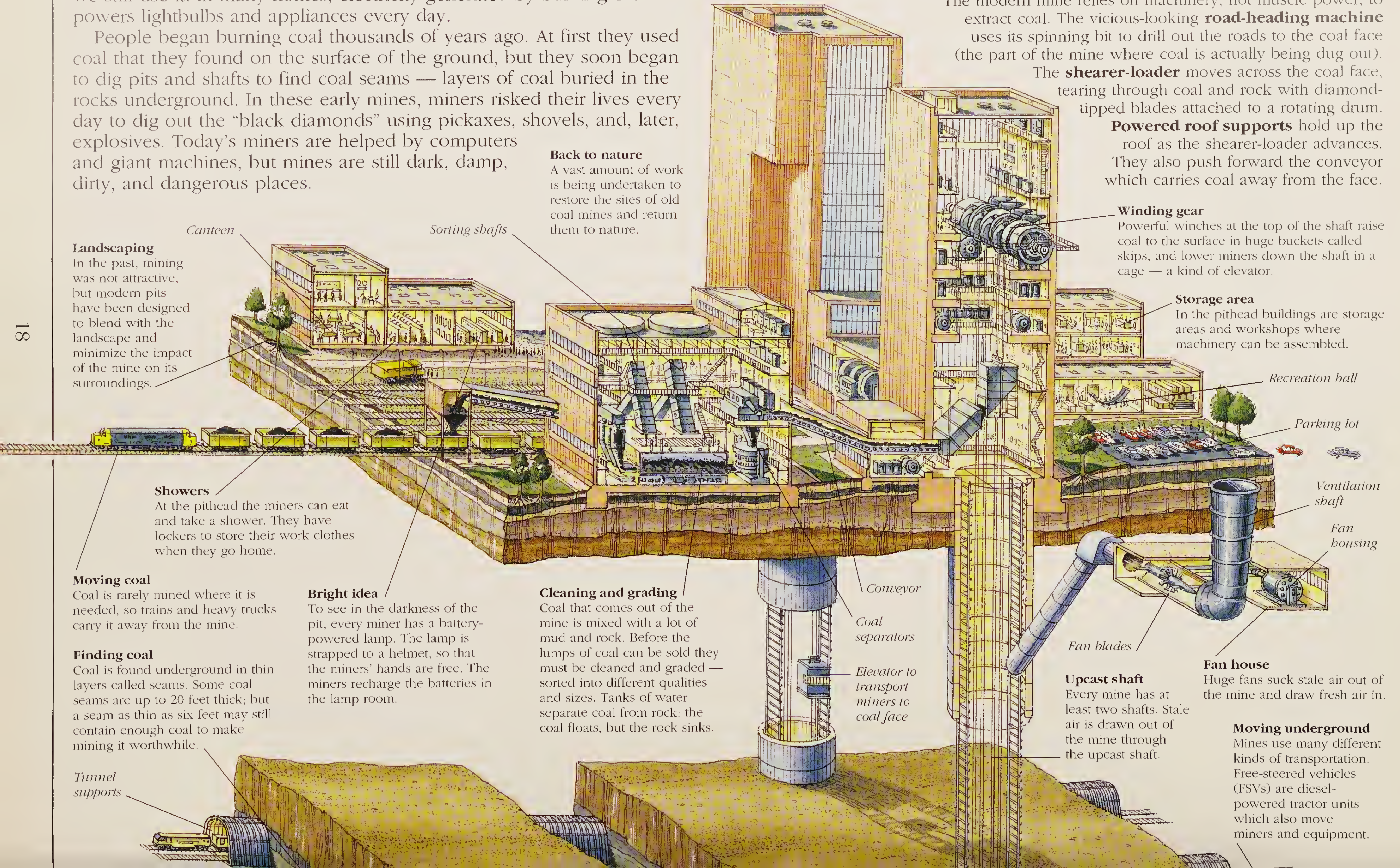
MINING MACHINERY


Road-heading machine


Shearer-loader


Powered roof supports

The modern mine relies on machinery, not muscle power, to extract coal. The vicious-looking **road-heading machine** uses its spinning bit to drill out the roads to the coal face (the part of the mine where coal is actually being dug out). The **shearer-loader** moves across the coal face, tearing through coal and rock with diamond-tipped blades attached to a rotating drum. **Powered roof supports** hold up the roof as the shearer-loader advances. They also push forward the conveyor which carries coal away from the face.



Back to nature
A vast amount of work is being undertaken to restore the sites of old coal mines and return them to nature.

Winding gear
Powerful winches at the top of the shaft raise coal to the surface in huge buckets called skips, and lower miners down the shaft in a cage — a kind of elevator.

Landscaping
In the past, mining was not attractive, but modern pits have been designed to blend with the landscape and minimize the impact of the mine on its surroundings.

Storage area
In the pithead buildings are storage areas and workshops where machinery can be assembled.

Showers
At the pithead the miners can eat and take a shower. They have lockers to store their work clothes when they go home.

Moving coal
Coal is rarely mined where it is needed, so trains and heavy trucks carry it away from the mine.

Finding coal
Coal is found underground in thin layers called seams. Some coal seams are up to 20 feet thick; but a seam as thin as six feet may still contain enough coal to make mining it worthwhile.

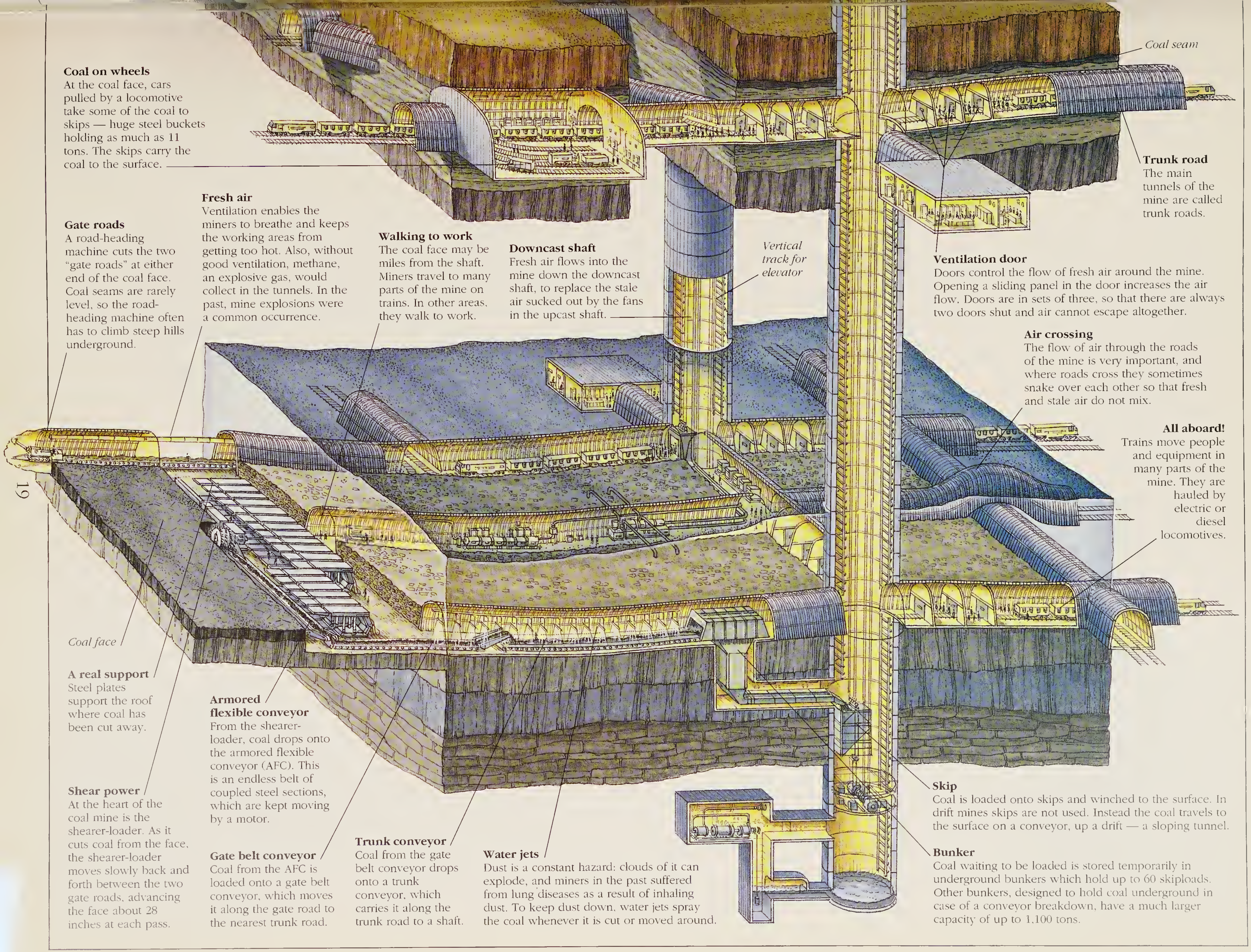
Bright idea
To see in the darkness of the pit, every miner has a battery-powered lamp. The lamp is strapped to a helmet, so that the miners' hands are free. The miners recharge the batteries in the lamp room.

Cleaning and grading
Coal that comes out of the mine is mixed with a lot of mud and rock. Before the lumps of coal can be sold they must be cleaned and graded — sorted into different qualities and sizes. Tanks of water separate coal from rock: the coal floats, but the rock sinks.

Upcast shaft
Every mine has at least two shafts. Stale air is drawn out of the mine through the upcast shaft.

Fan house
Huge fans suck stale air out of the mine and draw fresh air in.

Moving underground
Mines use many different kinds of transportation. Free-steered vehicles (FSVs) are diesel-powered tractor units which also move miners and equipment.



Coal on wheels
At the coal face, cars pulled by a locomotive take some of the coal to skips — huge steel buckets holding as much as 11 tons. The skips carry the coal to the surface.

Gate roads
A road-heading machine cuts the two "gate roads" at either end of the coal face. Coal seams are rarely level, so the road-heading machine often has to climb steep hills underground.

Fresh air
Ventilation enables the miners to breathe and keeps the working areas from getting too hot. Also, without good ventilation, methane, an explosive gas, would collect in the tunnels. In the past, mine explosions were a common occurrence.

Walking to work
The coal face may be miles from the shaft. Miners travel to many parts of the mine on trains. In other areas, they walk to work.

Downcast shaft
Fresh air flows into the mine down the downcast shaft, to replace the stale air sucked out by the fans in the upcast shaft.

Trunk road
The main tunnels of the mine are called trunk roads.

Ventilation door
Doors control the flow of fresh air around the mine. Opening a sliding panel in the door increases the air flow. Doors are in sets of three, so that there are always two doors shut and air cannot escape altogether.

Air crossing
The flow of air through the roads of the mine is very important, and where roads cross they sometimes snake over each other so that fresh and stale air do not mix.

All aboard!
Trains move people and equipment in many parts of the mine. They are hauled by electric or diesel locomotives.

A real support
Steel plates support the roof where coal has been cut away.

Shear power
At the heart of the coal mine is the shearer-loader. As it cuts coal from the face, the shearer-loader moves slowly back and forth between the two gate roads, advancing the face about 28 inches at each pass.

Armored flexible conveyor
From the shearer-loader, coal drops onto the armored flexible conveyor (AFC). This is an endless belt of coupled steel sections, which are kept moving by a motor.

Gate belt conveyor
Coal from the AFC is loaded onto a gate belt conveyor, which moves it along the gate road to the nearest trunk road.

Trunk conveyor
Coal from the gate belt conveyor drops onto a trunk conveyor, which carries it along the trunk road to a shaft.

Water jets
Dust is a constant hazard: clouds of it can explode, and miners in the past suffered from lung diseases as a result of inhaling dust. To keep dust down, water jets spray the coal whenever it is cut or moved around.

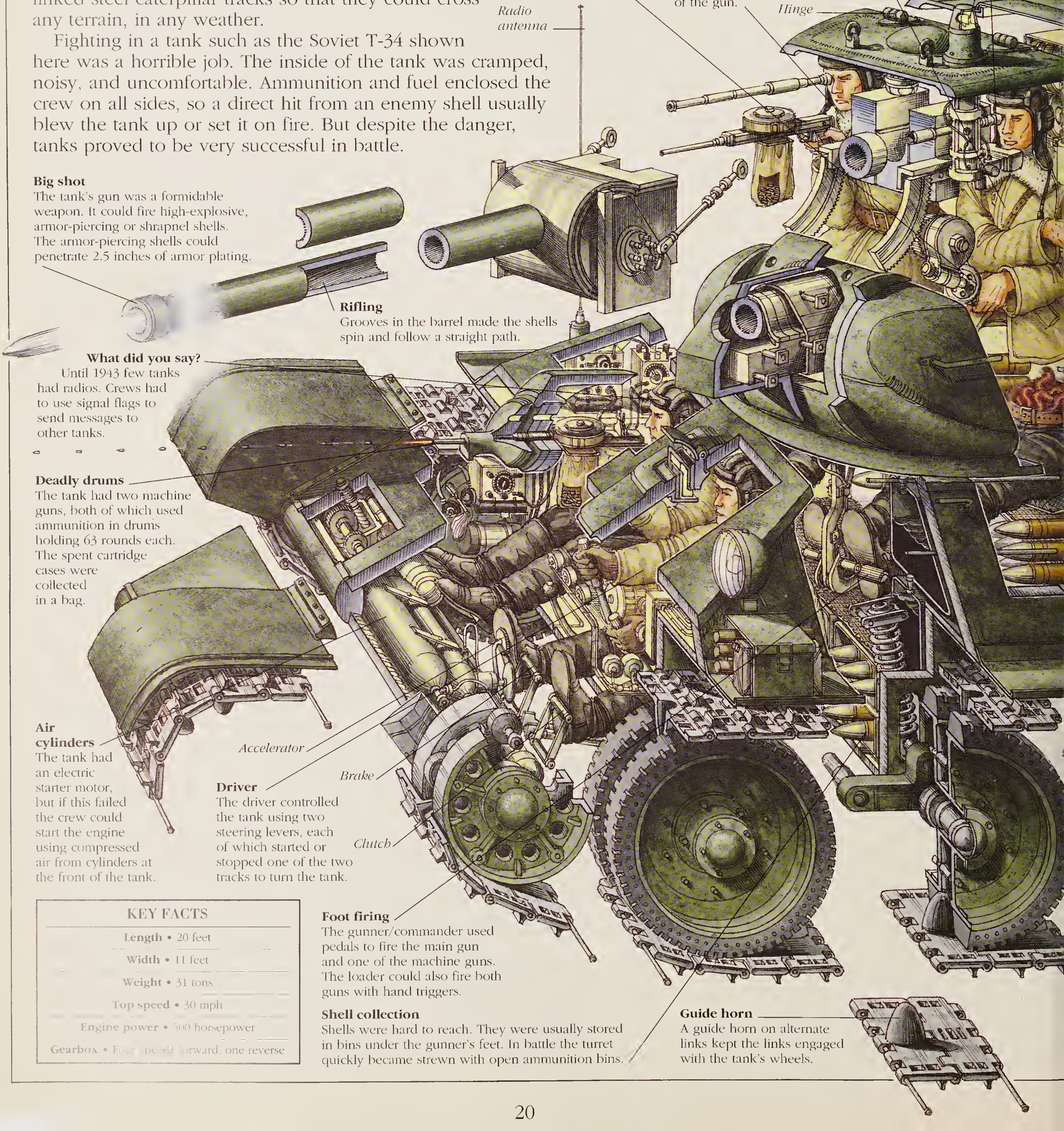
Skip
Coal is loaded onto skips and winched to the surface. In drift mines skips are not used. Instead the coal travels to the surface on a conveyor, up a drift — a sloping tunnel.

Bunker
Coal waiting to be loaded is stored temporarily in underground bunkers which hold up to 60 skiploads. Other bunkers, designed to hold coal underground in case of a conveyor breakdown, have a much larger capacity of up to 1,100 tons.

TANK

Five hundred years ago, the Italian artist and inventor Leonardo da Vinci (1452-1519) imagined the terrible fighting machine we now call the "tank." It could cross muddy battlefields with ease and was protected from attack by metal armor. Early tanks, used during World War I (1914-1918), had only limited success, but by the start of World War II in 1939, European armies had large numbers of tanks. They were all equipped with linked steel caterpillar tracks so that they could cross any terrain, in any weather.

Fighting in a tank such as the Soviet T-34 shown here was a horrible job. The inside of the tank was cramped, noisy, and uncomfortable. Ammunition and fuel enclosed the crew on all sides, so a direct hit from an enemy shell usually blew the tank up or set it on fire. But despite the danger, tanks proved to be very successful in battle.



Elevation control
Turning the elevation wheel raised or lowered the gun. The control was hard to operate, and if the gunner had long legs, the wheel banged his knees when he turned it.

Dual role
The tank had a crew of only four (most tanks have crews of five or more) so the commander also had to act as gunner. In practice he was overworked and did neither job well.

Loader
The loader had an uncomfortable job. The ammunition bin lids were hard to get off, and the cramped turret made it difficult to lift the 21-pound shells to the breech (end) of the gun.

In the sights
The gunner/commander aimed the gun using one of two sights. One sight provided a view through a periscope on the turret roof. The other gunsight was a telescope pointing directly forward.

Big shot
The tank's gun was a formidable weapon. It could fire high-explosive, armor-piercing or shrapnel shells. The armor-piercing shells could penetrate 2.5 inches of armor plating.

Rifling
Grooves in the barrel made the shells spin and follow a straight path.

What did you say?
Until 1943 few tanks had radios. Crews had to use signal flags to send messages to other tanks.

Deadly drums
The tank had two machine guns, both of which used ammunition in drums holding 63 rounds each. The spent cartridge cases were collected in a bag.

Air cylinders
The tank had an electric starter motor, but if this failed the crew could start the engine using compressed air from cylinders at the front of the tank.

Driver
The driver controlled the tank using two steering levers, each of which started or stopped one of the two tracks to turn the tank.

Foot firing
The gunner/commander used pedals to fire the main gun and one of the machine guns. The loader could also fire both guns with hand triggers.

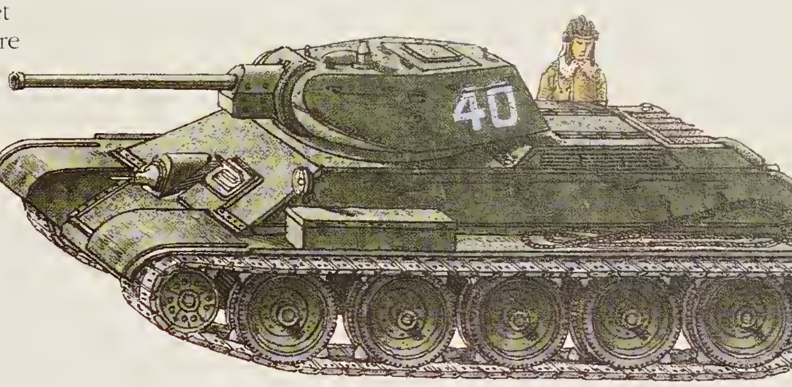
Shell collection
Shells were hard to reach. They were usually stored in bins under the gunner's feet. In battle the turret quickly became strewn with open ammunition bins.

Guide horn
A guide horn on alternate links kept the links engaged with the tank's wheels.

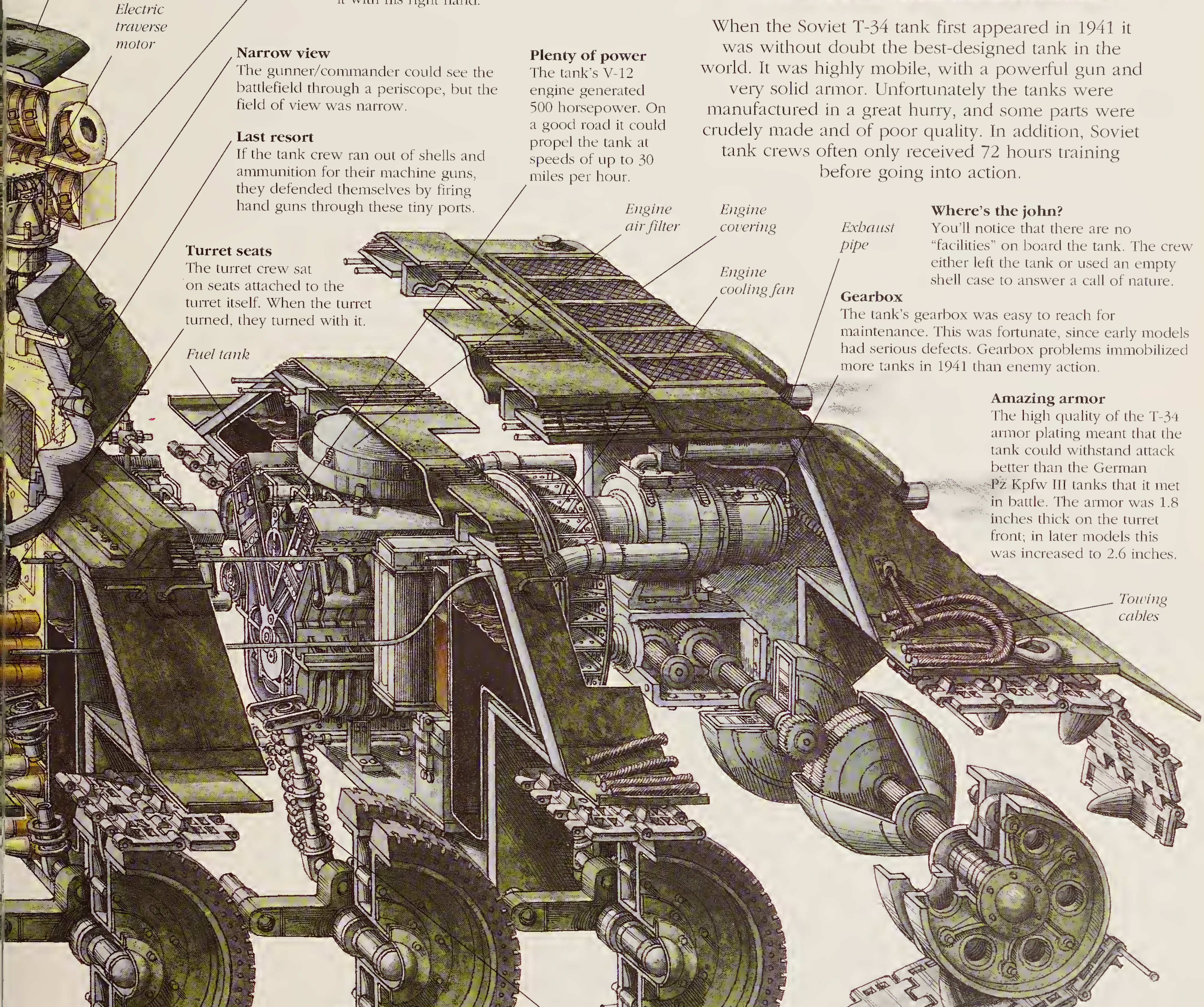
KEY FACTS

Length • 20 feet
Width • 11 feet
Weight • 31 tons
Top speed • 30 mph
Engine power • 500 horsepower
Gearbox • Four speeds forward, one reverse

DEADLY WEAPON



When the Soviet T-34 tank first appeared in 1941 it was without doubt the best-designed tank in the world. It was highly mobile, with a powerful gun and very solid armor. Unfortunately the tanks were manufactured in a great hurry, and some parts were crudely made and of poor quality. In addition, Soviet tank crews often only received 72 hours training before going into action.



Design flaw
The turret hatch opened forward, but when open it blocked the view of the way ahead. Consequently, Soviet tank commanders could not observe the battle from the open hatch without exposing themselves to enemy fire.

Tough turret
The turret was the part of the tank that housed the large gun. It was made of armor-plated steel and could traverse, or rotate, in a complete circle.

Crude construction
T-34 tanks were crudely made compared with their German and British counterparts. Soviet engineering was primitive and resources were scarce, so the factories carefully ground and polished only where absolutely necessary. But the rough finish did not reduce the tank's effectiveness.

All the way around
There was a motor to traverse the turret, and the gunner could also use a hand wheel for traversing. However, the hand wheel was in an awkward position, and the gunner had to reach across and turn it with his right hand.

Narrow view
The gunner/commander could see the battlefield through a periscope, but the field of view was narrow.

Last resort
If the tank crew ran out of shells and ammunition for their machine guns, they defended themselves by firing hand guns through these tiny ports.

Plenty of power
The tank's V-12 engine generated 500 horsepower. On a good road it could propel the tank at speeds of up to 30 miles per hour.

Turret seats
The turret crew sat on seats attached to the turret itself. When the turret turned, they turned with it.

Where's the john?
You'll notice that there are no "facilities" on board the tank. The crew either left the tank or used an empty shell case to answer a call of nature.

Gearbox
The tank's gearbox was easy to reach for maintenance. This was fortunate, since early models had serious defects. Gearbox problems immobilized more tanks in 1941 than enemy action.

Amazing armor
The high quality of the T-34 armor plating meant that the tank could withstand attack better than the German Pz Kpfw III tanks that it met in battle. The armor was 1.8 inches thick on the turret front; in later models this was increased to 2.6 inches.

Making tracks
The manganese-steel tracks spread the enormous weight of the tank, so that it did not sink into the mud of the battlefield. Ground pressure beneath the track was very low — only about double the pressure under a human foot, and less than half the pressure under a car tire.

Gripping grousers
Bolt-on plates, called grousers, provided extra grip in mud or snow.

Wheels
Because of a shortage of rubber in 1942, T-34 tanks were made with solid metal wheels. But this caused terrible vibration that shook parts loose. The problem was solved by putting rubber treads on the first and fifth wheels.

Suspension
The tank's suspension gave a comfortable ride but made it difficult to aim the gun accurately while the tank was moving. Modern tanks solve this problem with devices that stabilize the gun.

OIL RIG

Putting gasoline in a car couldn't be simpler. But extracting oil from which to make the gasoline is difficult. To understand the challenge of drilling for oil, think about standing at the top of a six-foot step ladder. Most of the ladder is under water. Now drill a hole the width of a pencil in the ground beneath the ladder. You need a long drill, because the hole needs to be 100 feet deep. Sounds difficult? Drilling for oil at sea is much harder.

Much of the world's oil is buried under the sea. Some oil production platforms are more than 700 feet high, but only a quarter shows above the waves. The rest is a strong frame anchored to the sea bed. The platform supports the rig — the apparatus that drills down to the oil — as well as storage tanks, pumps, and living quarters for the workers, who live on the rig for two weeks at a time.

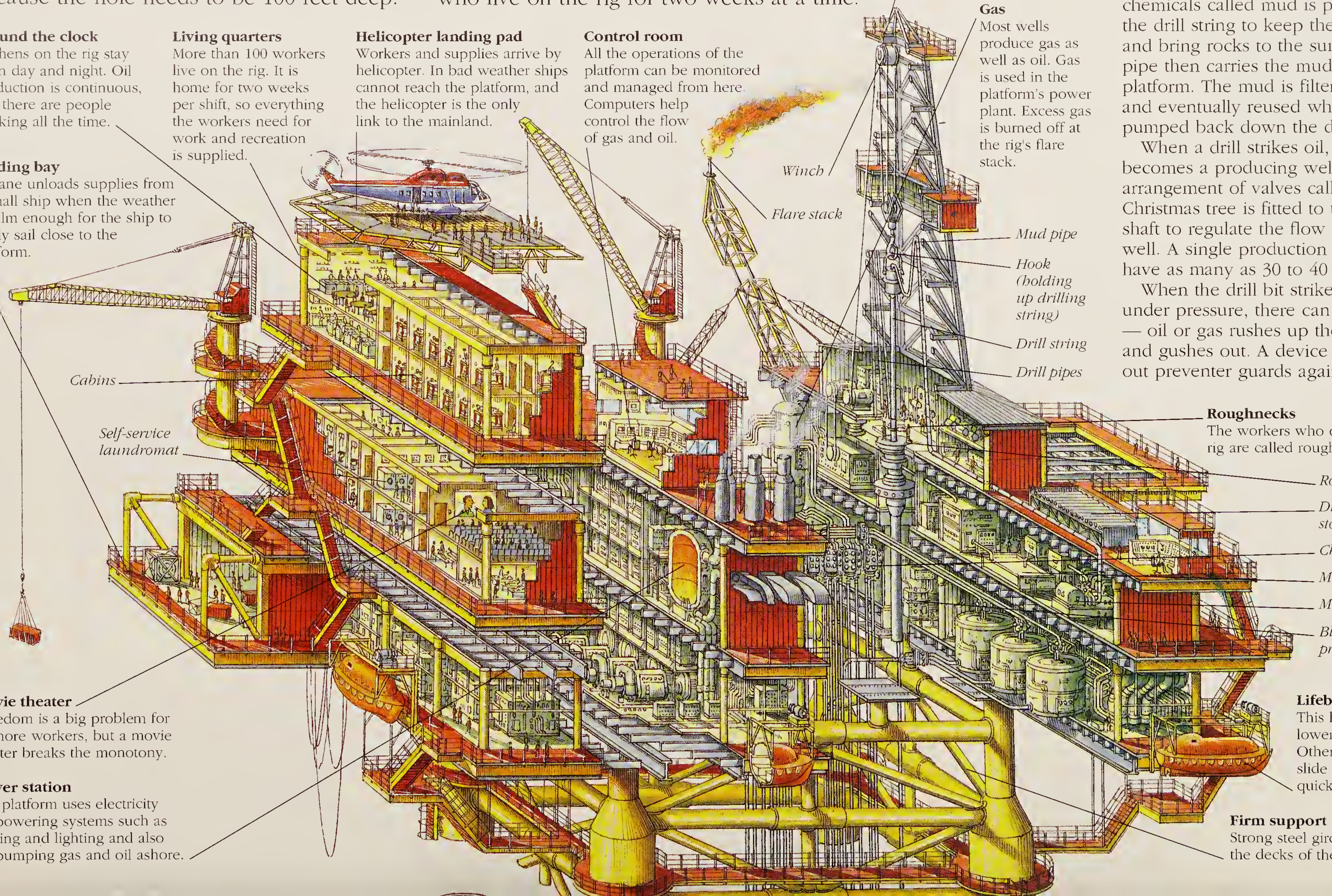
DRILLING FOR OIL

The part of the platform that drills down to reach the oil reserves is called the rig. The rig's motor turns a rotary table, which then turns a long shaft, called the drill string, which has a drill bit on the end. The drill bit has hard teeth, which cut through the rock below. As the shaft gets deeper, the drillers add on 30-foot pieces of pipe. The most visible part of the entire oil platform, called the derrick, is 200 feet high and supports the winch and crane that hold up the drill string. The drill string may weigh hundreds of tons, and the crane must be powerful enough to pull the entire string from the shaft.

As drilling progresses, a mix of chemicals called mud is pumped down the drill string to keep the drill bit cool and bring rocks to the surface. The mud pipe then carries the mud back to the platform. The mud is filtered, stored, and eventually reused when it is pumped back down the drill string.

When a drill strikes oil, the shaft becomes a producing well. An arrangement of valves called a Christmas tree is fitted to the top of the shaft to regulate the flow of oil from the well. A single production platform may have as many as 30 to 40 wells.

When the drill bit strikes oil or gas under pressure, there can be a blow-out — oil or gas rushes up the drill pipe and gushes out. A device called a blow-out preventer guards against this.



Around the clock
Kitchens on the rig stay open day and night. Oil production is continuous, and there are people working all the time.

Living quarters
More than 100 workers live on the rig. It is home for two weeks per shift, so everything the workers need for work and recreation is supplied.

Helicopter landing pad
Workers and supplies arrive by helicopter. In bad weather ships cannot reach the platform, and the helicopter is the only link to the mainland.

Control room
All the operations of the platform can be monitored and managed from here. Computers help control the flow of gas and oil.

Gas
Most wells produce gas as well as oil. Gas is used in the platform's power plant. Excess gas is burned off at the rig's flare stack.

Loading bay
A crane unloads supplies from a small ship when the weather is calm enough for the ship to safely sail close to the platform.

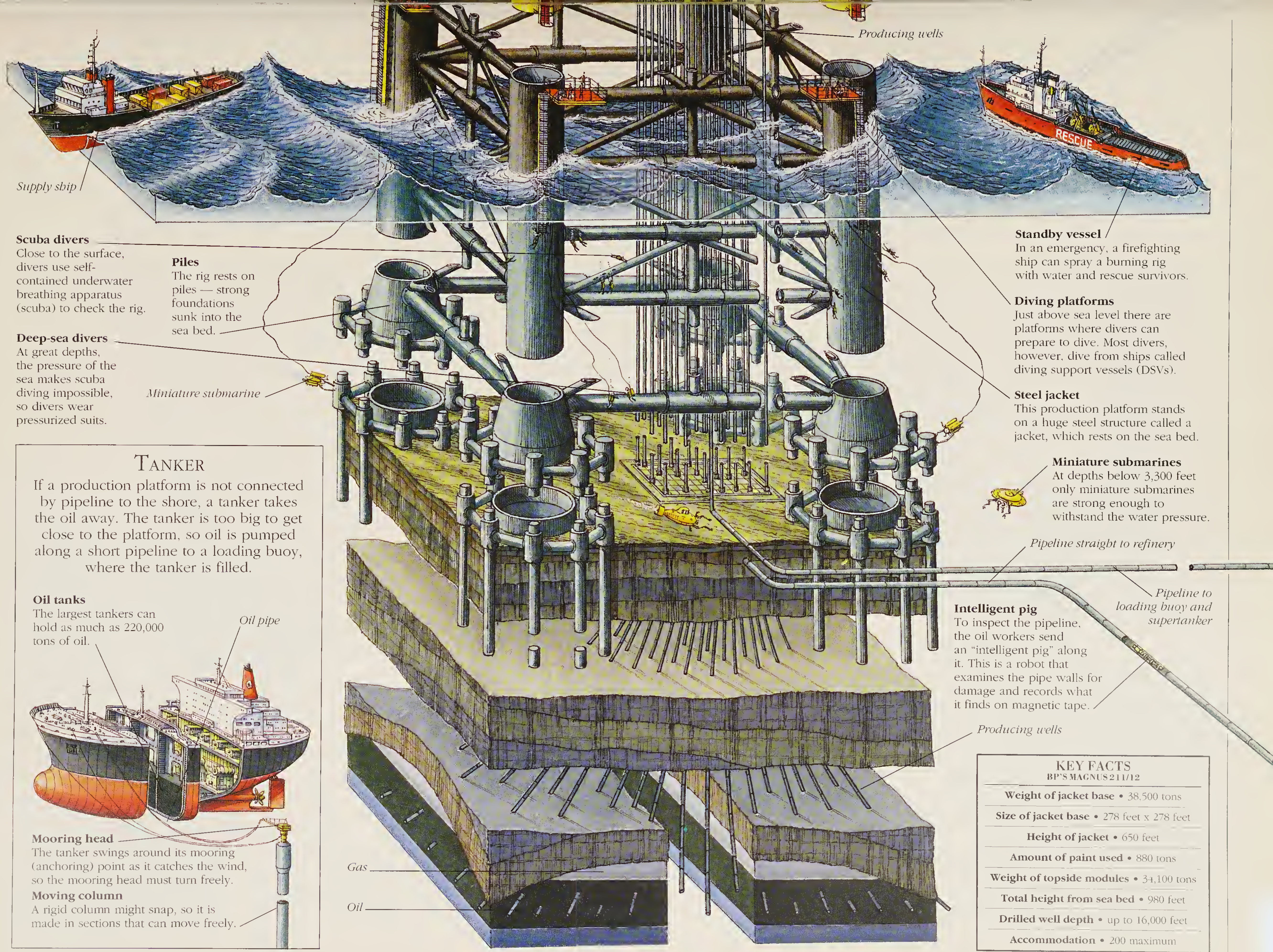
Roughnecks
The workers who operate the drilling rig are called roughnecks.

Movie theater
Boredom is a big problem for offshore workers, but a movie theater breaks the monotony.

Power station
The platform uses electricity for powering systems such as heating and lighting and also for pumping gas and oil ashore.

Lifeboat
This lifeboat can be lowered into the water. Other kinds of lifeboats slide down ramps for a quick escape.

Firm support
Strong steel girders support the decks of the platform.



Scuba divers
Close to the surface, divers use self-contained underwater breathing apparatus (scuba) to check the rig.

Piles
The rig rests on piles — strong foundations sunk into the sea bed.

Deep-sea divers
At great depths, the pressure of the sea makes scuba diving impossible, so divers wear pressurized suits.

Standby vessel
In an emergency, a firefighting ship can spray a burning rig with water and rescue survivors.

Diving platforms
Just above sea level there are platforms where divers can prepare to dive. Most divers, however, dive from ships called diving support vessels (DSVs).

Steel jacket
This production platform stands on a huge steel structure called a jacket, which rests on the sea bed.

Miniature submarines
At depths below 3,300 feet only miniature submarines are strong enough to withstand the water pressure.

Intelligent pig
To inspect the pipeline, the oil workers send an "intelligent pig" along it. This is a robot that examines the pipe walls for damage and records what it finds on magnetic tape.

TANKER

If a production platform is not connected by pipeline to the shore, a tanker takes the oil away. The tanker is too big to get close to the platform, so oil is pumped along a short pipeline to a loading buoy, where the tanker is filled.

Oil tanks
The largest tankers can hold as much as 220,000 tons of oil.

Mooring head
The tanker swings around its mooring (anchoring) point as it catches the wind, so the mooring head must turn freely.

Moving column
A rigid column might snap, so it is made in sections that can move freely.

KEY FACTS
BP'S MAGNUS 211/12

Weight of jacket base	38,500 tons
Size of jacket base	278 feet x 278 feet
Height of jacket	650 feet
Amount of paint used	880 tons
Weight of topside modules	34,100 tons
Total height from sea bed	980 feet
Drilled well depth	up to 16,000 feet
Accommodation	200 maximum

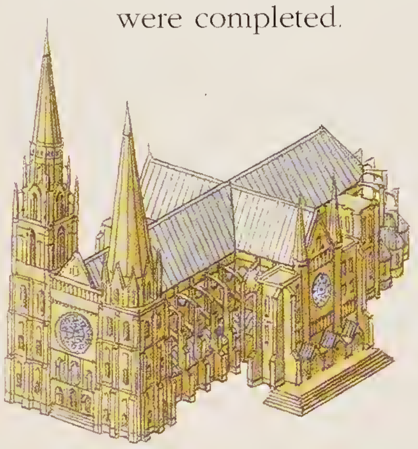
CATHEDRAL

Soaring high above the city skyline, the spires and roofs of a cathedral are a breathtaking sight. Cathedrals are just as amazing inside. They astonish the visitor with their stained glass and beautiful stone and wood carved into intricate shapes and patterns. When most European cathedrals were built centuries ago, everything in them had to be laboriously carved by hand. Cathedral builders were not thinking about tourists when they began their work. They were building a place of prayer and worship, for the glory of God.

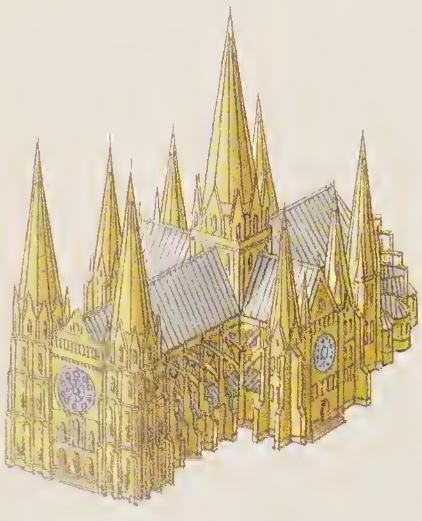
Today cathedrals still play an important part in the Christian religion. Each is the special central church of a diocese (religious district). The bishop of the diocese leads the worship in the cathedral.

JEWEL OF FRANCE

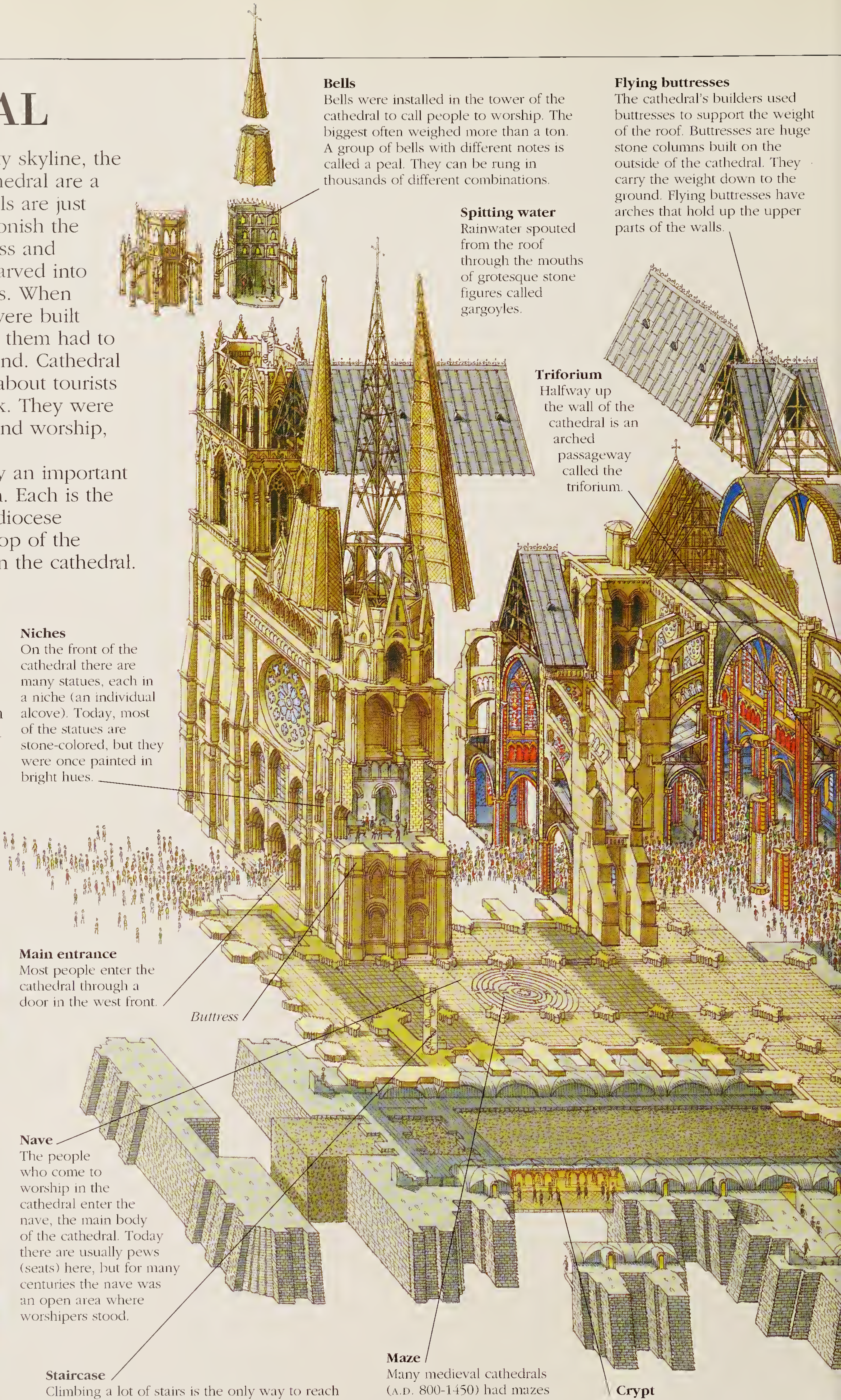
The cathedral cross-section on these pages is based on the famous cathedral at Chartres, France, which was built between 1195 and 1260 and is considered by many experts to be the most perfect of Europe's cathedrals. The original builders of Chartres envisioned the structure with nine towers, but only two were completed.



This is a view of the cathedral as it stands today.



The original plan of the cathedral had nine towers, including a massive central spire.



Bells
Bells were installed in the tower of the cathedral to call people to worship. The biggest often weighed more than a ton. A group of bells with different notes is called a peal. They can be rung in thousands of different combinations.

Flying buttresses
The cathedral's builders used buttresses to support the weight of the roof. Buttresses are huge stone columns built on the outside of the cathedral. They carry the weight down to the ground. Flying buttresses have arches that hold up the upper parts of the walls.

Spitting water
Rainwater spouted from the roof through the mouths of grotesque stone figures called gargoyles.

Triforium
Halfway up the wall of the cathedral is an arched passageway called the triforium.

Niches
On the front of the cathedral there are many statues, each in a niche (an individual alcove). Today, most of the statues are stone-colored, but they were once painted in bright hues.

Main entrance
Most people enter the cathedral through a door in the west front.

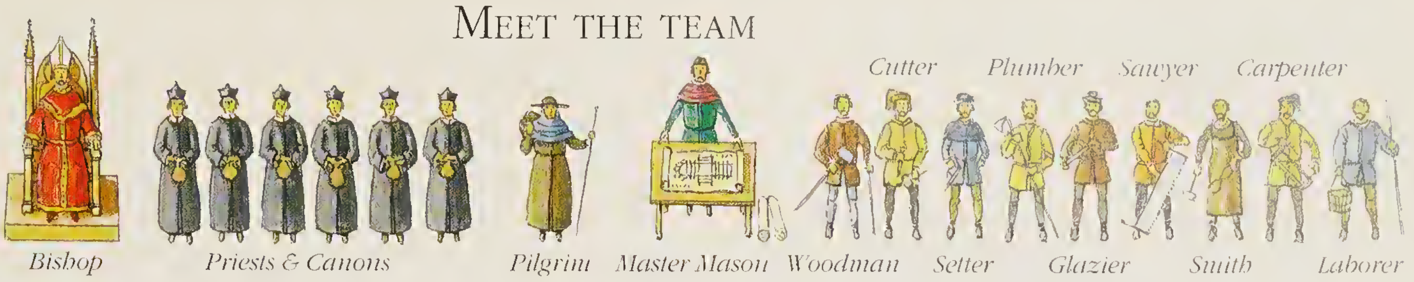
Nave
The people who come to worship in the cathedral enter the nave, the main body of the cathedral. Today there are usually pews (seats) here, but for many centuries the nave was an open area where worshipers stood.

Staircase
Climbing a lot of stairs is the only way to reach the roof, and this partly explains why fire destroyed so many cathedrals. To put out the flames, people passed buckets of water from hand to hand. Much of the water had spilled out by the time the buckets reached the fire.

Maze
Many medieval cathedrals (A.D. 800-1450) had mazes built into the floors. A walk along the maze probably represented a pilgrimage (holy journey) to Jerusalem in the Holy Land (now in Israel).

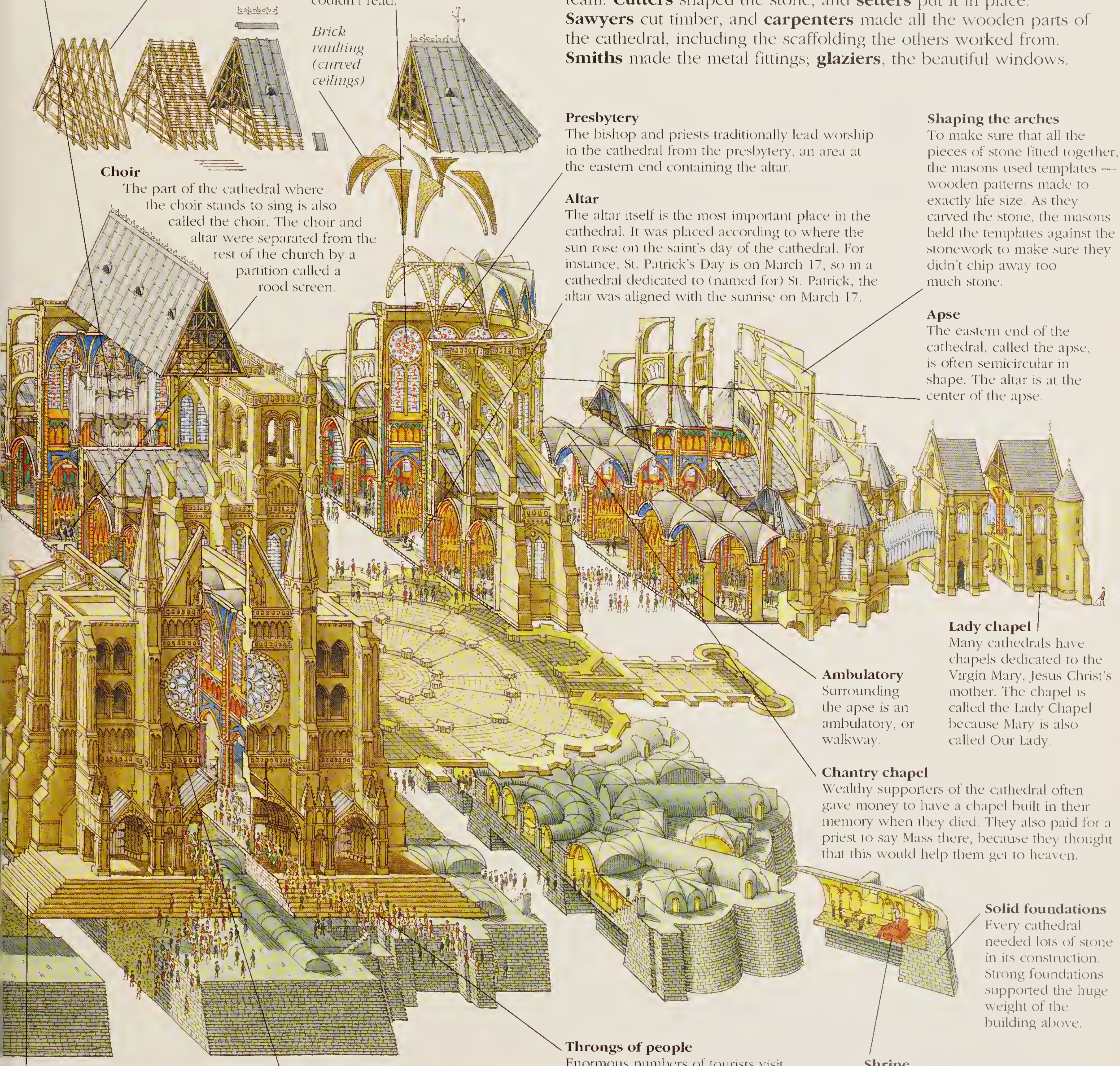
Crypt
Underneath much of the cathedral is a crypt — a kind of cellar. Often the crypt is a burial place for officials of the church and other important people.

MEET THE TEAM



The **bishop** was the leader of worship in the cathedral. He had help in organizing worship from **priests** and **canons**, and possibly from monks if the cathedral was attached to a monastery.

The **master mason**, who designed the structure, led the building team. **Cutters** shaped the stone, and **setters** put it in place. **Sawyers** cut timber, and **carpenters** made all the wooden parts of the cathedral, including the scaffolding the others worked from. **Smiths** made the metal fittings; **glaziers**, the beautiful windows.



Organ
Music has been important in Christian worship for centuries. Organs were first used in European cathedrals more than a thousand years ago.

Roof beams
The cathedral roof is a network of huge timbers and thin strips of wood. A thin skin of lead or copper makes the roof waterproof.

Stained glass
Stained-glass windows held thousands of pieces of colored glass. Each window told a Bible story in pictures, because most people couldn't read.

Choir
The part of the cathedral where the choir stands to sing is also called the choir. The choir and altar were separated from the rest of the church by a partition called a rood screen.

Presbytery
The bishop and priests traditionally lead worship in the cathedral from the presbytery, an area at the eastern end containing the altar.

Altar
The altar itself is the most important place in the cathedral. It was placed according to where the sun rose on the saint's day of the cathedral. For instance, St. Patrick's Day is on March 17, so in a cathedral dedicated to (named for) St. Patrick, the altar was aligned with the sunrise on March 17.

Shaping the arches
To make sure that all the pieces of stone fitted together, the masons used templates — wooden patterns made to exactly life size. As they carved the stone, the masons held the templates against the stonework to make sure they didn't chip away too much stone.

Apse
The eastern end of the cathedral, called the apse, is often semicircular in shape. The altar is at the center of the apse.

Lady chapel
Many cathedrals have chapels dedicated to the Virgin Mary, Jesus Christ's mother. The chapel is called the Lady Chapel because Mary is also called Our Lady.

Ambulatory
Surrounding the apse is an ambulatory, or walkway.

Chantry chapel
Wealthy supporters of the cathedral often gave money to have a chapel built in their memory when they died. They also paid for a priest to say Mass there, because they thought that this would help them get to heaven.

Solid foundations
Every cathedral needed lots of stone in its construction. Strong foundations supported the huge weight of the building above.

Chip off the old block
Much of the cathedral was prefabricated: masons carved the stonework roughly to shape at the quarry and finished it off at the building site.

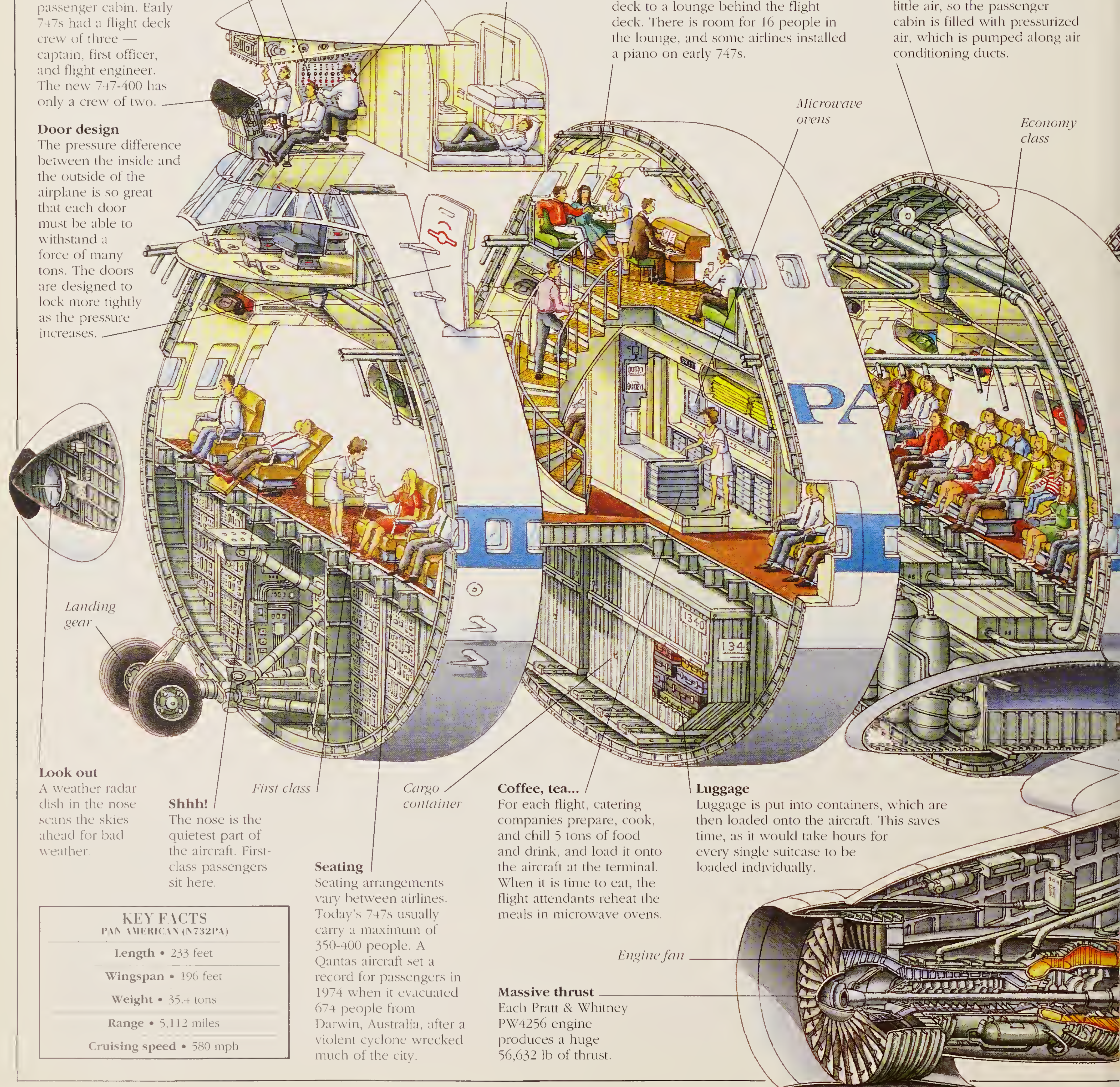
Transept
The transepts cross the nave. They make the plan of the cathedral into a cross shape, to remind Christians of the wooden cross on which Christ was nailed.

Throngs of people
Enormous numbers of tourists visit Europe's great cathedrals to wonder at the beautiful craftsmanship. Some may even pause and pray. In the past, cathedrals were just as crowded, but with pilgrims — people who traveled to cathedrals to pray and worship.

Shrine
Cathedrals often had shrines. These were chambers containing relics — objects of special religious importance, such as the bones of a saint or a piece of Christ's cross. Many people visited cathedrals to worship at shrines.

JUMBO JET

Imagine a small town and all its people suddenly plucked from the ground and flying through the air at hundreds of miles an hour. Imagine this flying town has power, heating, and sewage plants and carries enough food and drink to keep everyone well fed for a day. Now imagine hundreds of such towns flying high above tall mountains, deep oceans, and polar icecaps. They carry their human cargo on a strict timetable, in greater safety than a car. But this flying town is not imaginary. It is a Boeing 747 airplane, or jumbo jet. The 747 is the world's largest passenger airplane and can carry more than 400 people. The 747 began service in 1969. The aircraft shown here was one of the first — Pan Am's N732. Since then, 747s have flown a billion people more than 15 billion miles — that's like flying everybody on the earth to the moon and back 6,000 times.



Flight deck
The flight deck of the 747 is above the passenger cabin. Early 747s had a flight deck crew of three — captain, first officer, and flight engineer. The new 747-400 has only a crew of two.

Door design
The pressure difference between the inside and the outside of the airplane is so great that each door must be able to withstand a force of many tons. The doors are designed to lock more tightly as the pressure increases.

Tunes in the sky
A spiral staircase connects the lower deck to a lounge behind the flight deck. There is room for 16 people in the lounge, and some airlines installed a piano on early 747s.

A breath of fresh air
At high altitudes, there is very little air, so the passenger cabin is filled with pressurized air, which is pumped along air conditioning ducts.

Look out
A weather radar dish in the nose scans the skies ahead for bad weather.

Shhh!
The nose is the quietest part of the aircraft. First-class passengers sit here.

Seating
Seating arrangements vary between airlines. Today's 747s usually carry a maximum of 350-400 people. A Qantas aircraft set a record for passengers in 1974 when it evacuated 674 people from Darwin, Australia, after a violent cyclone wrecked much of the city.

Coffee, tea...
For each flight, catering companies prepare, cook, and chill 5 tons of food and drink, and load it onto the aircraft at the terminal. When it is time to eat, the flight attendants reheat the meals in microwave ovens.

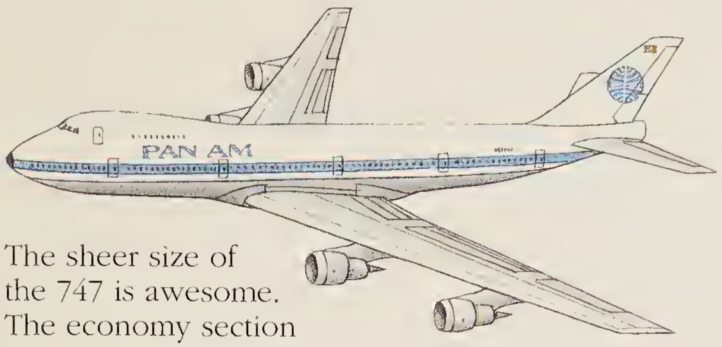
Luggage
Luggage is put into containers, which are then loaded onto the aircraft. This saves time, as it would take hours for every single suitcase to be loaded individually.

Massive thrust
Each Pratt & Whitney PW4256 engine produces a huge 56,632 lb of thrust.

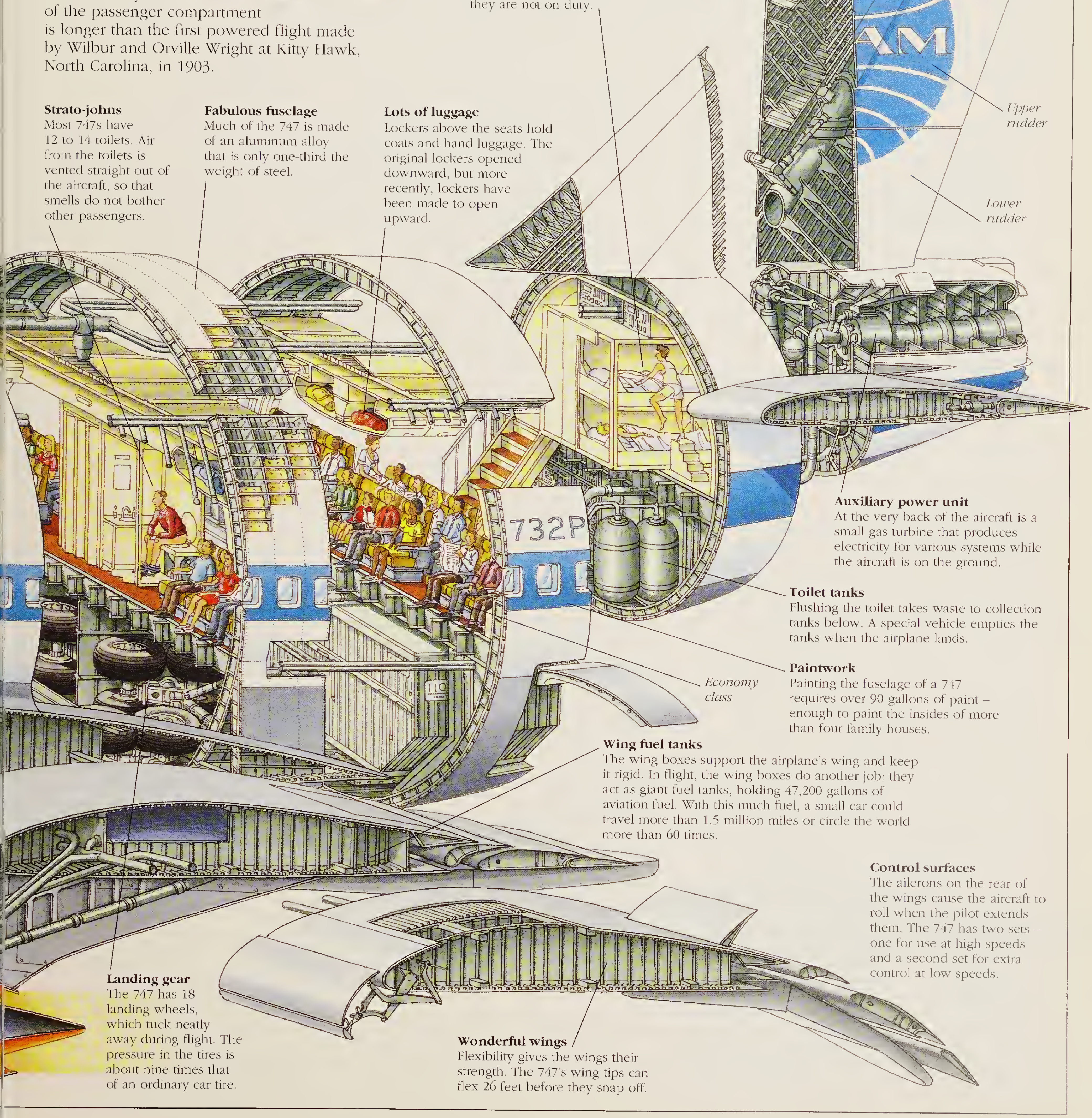
KEY FACTS
PAN AMERICAN (N732PA)

Length	233 feet
Wingspan	196 feet
Weight	35.4 tons
Range	5,112 miles
Cruising speed	580 mph

GIANT OF THE AIR



The sheer size of the 747 is awesome. The economy section of the passenger compartment is longer than the first powered flight made by Wilbur and Orville Wright at Kitty Hawk, North Carolina, in 1903.



Tall tail
The tip of the tail fin of the 747 is 63 feet above the ground. It would block the view from the top windows of a six-story building. The massive rudder section of the tail turns the airplane right or left in flight.

And so to bed
To combat crew tiredness, 747s have a crew compartment with bunk beds so that crew members can rest when they are not on duty.

Strato-johns
Most 747s have 12 to 14 toilets. Air from the toilets is vented straight out of the aircraft, so that smells do not bother other passengers.

Fabulous fuselage
Much of the 747 is made of an aluminum alloy that is only one-third the weight of steel.

Lots of luggage
Lockers above the seats hold coats and hand luggage. The original lockers opened downward, but more recently, lockers have been made to open upward.

Auxiliary power unit
At the very back of the aircraft is a small gas turbine that produces electricity for various systems while the aircraft is on the ground.

Toilet tanks
Flushing the toilet takes waste to collection tanks below. A special vehicle empties the tanks when the airplane lands.

Paintwork
Painting the fuselage of a 747 requires over 90 gallons of paint – enough to paint the insides of more than four family houses.

Wing fuel tanks
The wing boxes support the airplane's wing and keep it rigid. In flight, the wing boxes do another job: they act as giant fuel tanks, holding 47,200 gallons of aviation fuel. With this much fuel, a small car could travel more than 1.5 million miles or circle the world more than 60 times.

Control surfaces
The ailerons on the rear of the wings cause the aircraft to roll when the pilot extends them. The 747 has two sets – one for use at high speeds and a second set for extra control at low speeds.

Landing gear
The 747 has 18 landing wheels, which tuck neatly away during flight. The pressure in the tires is about nine times that of an ordinary car tire.

Wonderful wings
Flexibility gives the wings their strength. The 747's wing tips can flex 26 feet before they snap off.

CAR FACTORY

Some people would say that robots make ideal factory workers. They don't stop for food, they don't get sick, they don't need to sleep, and they don't get bored. They are especially suited to factories that produce multiple numbers of the same product, such as cars. In a car factory, robots do most of the repetitive and tiring work. They lift, assemble, weld, paint, and perform many other tasks.

However, robots are not good at solving problems. When things go wrong, robots cannot cope. So human beings are still needed to control quality and keep production flowing smoothly.

Press shop
The section of the factory where body and floor panels are made is called the press shop.

Roll up!
Metal for the car's panels arrives in rolls. It has been coated with an anti-corrosion chemical layer. A remote-control crane unloads the roll from the trucks.

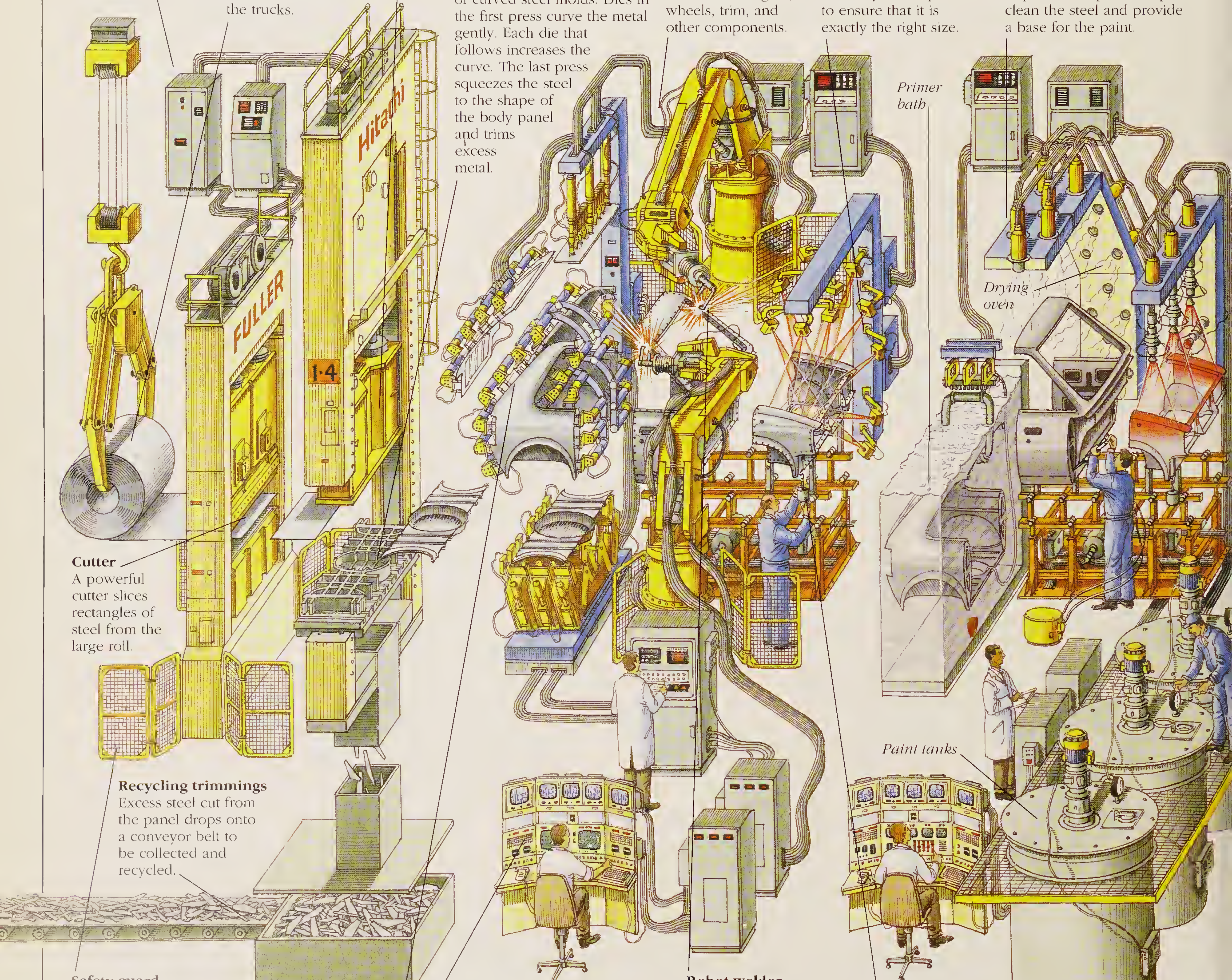
A pressing appointment
To shape the panels, the steel passes through a series of presses, each the height of a two-story house.

Dies
The presses squash the steel sheet between dies — pairs of curved steel molds. Dies in the first press curve the metal gently. Each die that follows increases the curve. The last press squeezes the steel to the shape of the body panel and trims excess metal.

Body shop
Panels move into storage before being assembled into a "body-in-white." This is a complete unpainted body, without the engine, wheels, trim, and other components.

Checking with lasers
To check that the assembly process is working perfectly, sample bodies are measured using a laser scanner. This measures the body at 350 points to ensure that it is exactly the right size.

Paint shop
It takes 25 hours to paint each body. Many different steps are needed to create a perfect finish. There isn't room to show them all, but preparation before painting requires 11 separate steps to clean the steel and provide a base for the paint.



Cutter
A powerful cutter slices rectangles of steel from the large roll.

Recycling trimmings
Excess steel cut from the panel drops onto a conveyor belt to be collected and recycled.

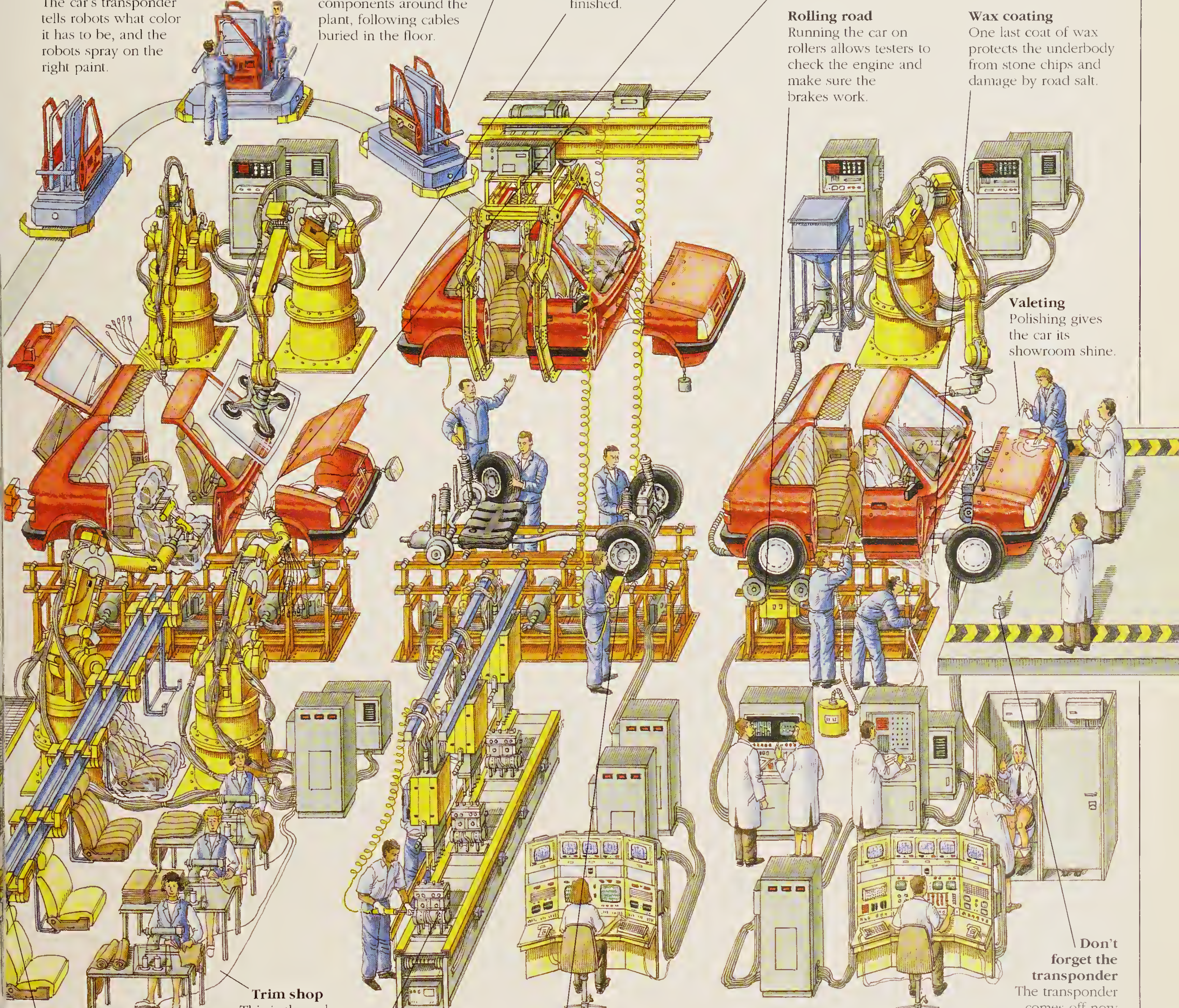
Safety guard
Gates keep people away from machines while they are operating. If workers try to operate machines with the gates open, an alarm sounds.

Positioning panels
Robot arms lift the body panels and position them on a jig — a framework that holds all the panels.

Quality control
Human workers monitor quality in the factory. For instance, computers check the electrical current being fed to the welders and alert human workers when it varies, so they can adjust it.

Robot welder
Robots first spot-weld the panels (stick them together by melting the metal with a very hot electric spark). Then other robots add more spot-welds to finish the joint.

Attaching a transponder
The factory must control the number of car types made. Each body has a transponder (radio transmitter/receiver), which will identify it throughout the production stages that follow.



First dip
After careful preparation, the body plunges into a bath which coats it with primer paint. This protects the body from corrosion and ensures that the paint will stick to it.

Bake in the oven until done
Between coats of paint, the body roasts in an oven at 180°F. After the final coat, the paint dries in an oven at 320°F.

A glossy finish
The car's transponder tells robots what color it has to be, and the robots spray on the right paint.

Don't slam the door!
After painting, the doors are removed for the next stage. This makes access to the car interior easier and simplifies assembly of the doors.

Robo-carrier
Doors move through the production process on robo-carriers. These are miniature transport robots that move the doors along while workers add components to them. Robo-carriers also transport components around the plant, following cables buried in the floor.

Finished doors
The doors rejoin their car body as it emerges from the components/trim shop.

Components/trim shop
In this section of the factory the car begins to look more like a car and less like a colored shell. Here the electrical system is added, and the passenger compartment is furnished and finished.

Fitting electrics
Small components such as lights and other "electrics" reach the area where they are fitted on a "just-in-time" basis. Stocks of components on the production line are kept low to save space. The transponder attached to each body automatically orders the right parts as the body approaches. A robot finds the component and delivers it just in time to be fitted.

The marriage conveyor
As the car nears the end of the production process, the body is married (joined) to the engine, steering, suspension, and transmission (the gearbox and related parts).

Rolling road
Running the car on rollers allows testers to check the engine and make sure the brakes work.

Wax coating
One last coat of wax protects the underbody from stone chips and damage by road salt.

Valeting
Polishing gives the car its showroom shine.

Overhead conveyor
Like many parts in the factory, seats move from the trim shop to the production line on overhead conveyors.

Trim shop
This is the only area of the factory that has not been changed by robots. Here, craftworkers cut and stitch carpets and seats using heavy-duty sewing machines.

Building engines
Some parts are manufactured in this factory, but others — even whole gearboxes — may be built in factories thousands of miles away.

Fitting wheels
Workers fit the wheels by hand, but they are helped by a tool that tightens all the wheel nuts at once.

Testing, testing
Many of the car's components are tested when they are manufactured and fitted — for example, the fuel tank is filled with air and immersed in water to check for leaks. However, each car gets a thorough check before it goes out to be sold.

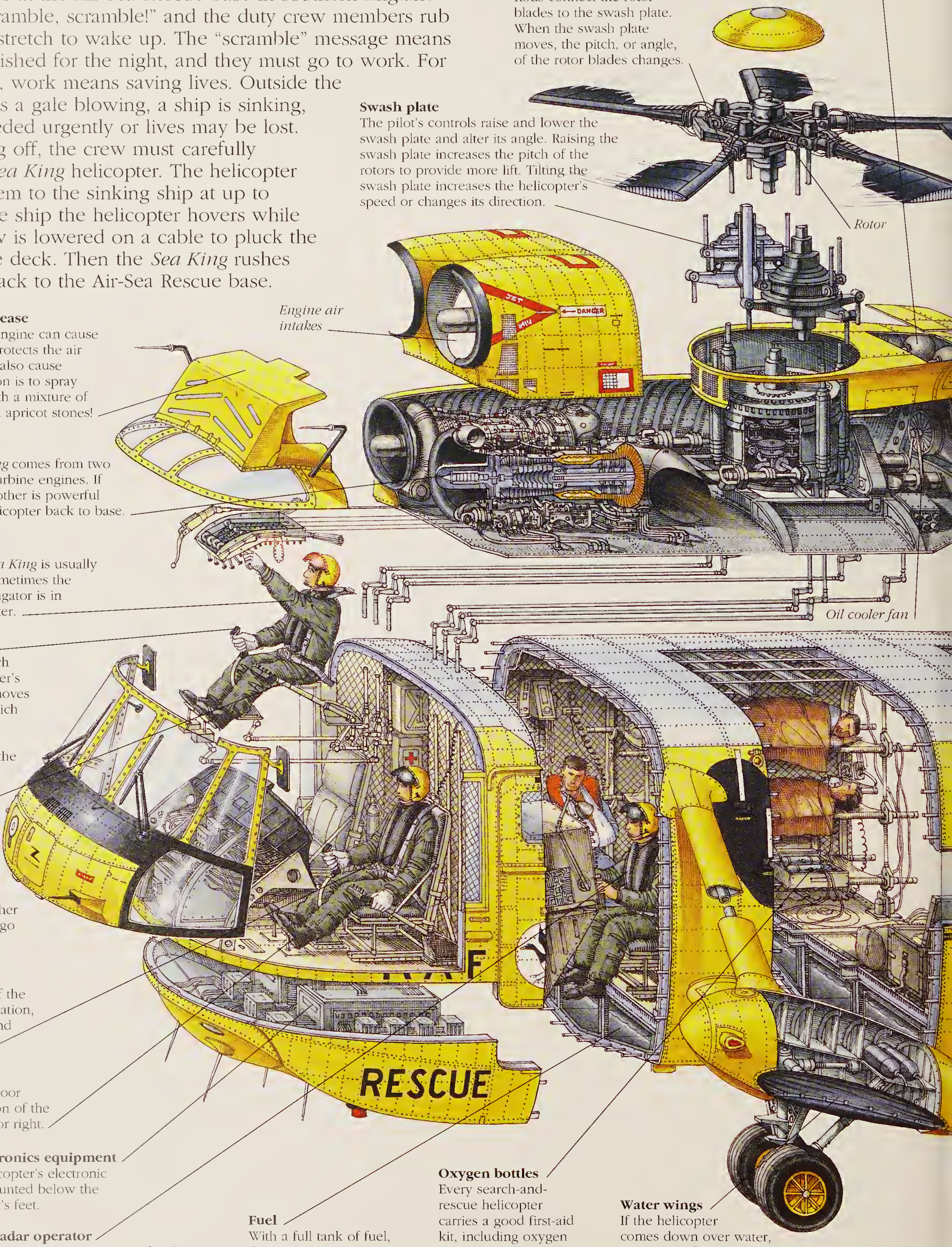
Don't forget the transponder
The transponder comes off now and goes back to the beginning of the production line.

Road test
Finally the finished car goes off for a road test.

HELICOPTER

A loudspeaker at the Air-Sea Rescue base in southern England blares, "Scramble, scramble!" and the duty crew members rub their eyes and stretch to wake up. The "scramble" message means that sleep is finished for the night, and they must go to work. For these four men, work means saving lives. Outside the window there is a gale blowing, a ship is sinking, and help is needed urgently or lives may be lost.

Before taking off, the crew must carefully prepare their *Sea King* helicopter. The helicopter then speeds them to the sinking ship at up to 155 mph. At the ship the helicopter hovers while one of the crew is lowered on a cable to pluck the sailors from the deck. Then the *Sea King* rushes the survivors back to the Air-Sea Rescue base.



Engine fire extinguisher bottles
The pilot can fill the engine compartment with foam to extinguish a fire there.

Blade pitch control rods
Rods connect the rotor blades to the swash plate. When the swash plate moves, the pitch, or angle, of the rotor blades changes.

Swash plate
The pilot's controls raise and lower the swash plate and alter its angle. Raising the swash plate increases the pitch of the rotors to provide more lift. Tilting the swash plate increases the helicopter's speed or changes its direction.

Pass the apricots, please
Objects entering the engine can cause damage, so a guard protects the air intake. Salt spray can also cause problems. One solution is to spray some engine parts with a mixture of chemicals and ground apricot stones!

Turbine
Power for the *Sea King* comes from two Rolls-Royce Gnome turbine engines. If one engine fails, the other is powerful enough to get the helicopter back to base.

Pilot
The captain of the *Sea King* is usually the pilot, although sometimes the radar operator or navigator is in charge of the helicopter.

Cyclic pitch lever
Moving the cyclic pitch lever tilts the helicopter's rotor. The *Sea King* moves in the direction in which the rotor is tilted. For example, pushing the lever forward moves the helicopter forward.

Collective pitch lever
The controls on this lever alter both the engine speed and the pitch of the rotors. Operating them together makes the helicopter go up or down.

Co-pilot
The responsibilities of the co-pilot include navigation, pre-flight planning, and briefing the captain.

Yaw control
Pedals on the cabin floor control yaw — rotation of the helicopter to the left or right.

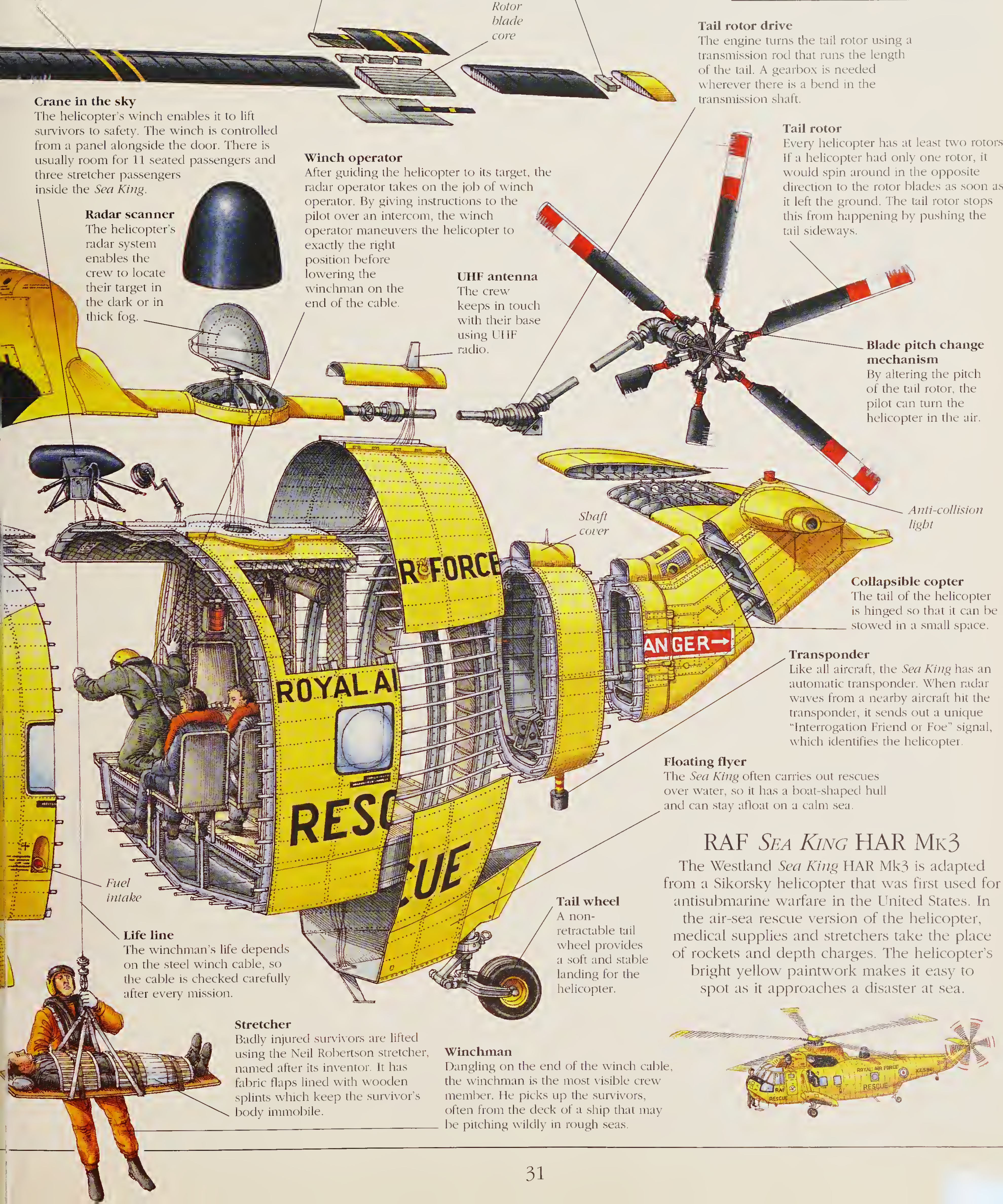
Radio and electronics equipment
Much of the helicopter's electronic equipment is mounted below the pilot and co-pilot's feet.

Radar operator
Navigation equipment and radar are the responsibility of the radar operator, who sits behind the pilot.

Fuel
With a full tank of fuel, the latest *Sea King* helicopters have a range of more than 720 miles.

Oxygen bottles
Every search-and-rescue helicopter carries a good first-aid kit, including oxygen cylinders. All members of the crew are trained in first aid.

Water wings
If the helicopter comes down over water, emergency flotation bags inflate with compressed air to keep the helicopter from sinking.



Rotor blade
The rotor is the assembly on the top of the helicopter that spins around. It holds the rotor blades, which make the helicopter fly by pushing down on the air underneath and creating lift. The blades also control the helicopter's direction. Tilting the rotor left and right turns the helicopter. Tilting it back and forth enables the helicopter to fly forward and backward.

Aluminum spar
The spine of each rotor blade is a D-shaped aluminum spar. To enable the crew to check for damage to the rotor blades, the spar contains gas at high pressure. Any loss of pressure lights a warning light in the cockpit indicating that a crack has formed.

In balance
Every blade must weigh exactly the same or the rotor will vibrate badly. Engineers insert weights into the blades to balance them.

KEY FACTS
WESTLAND SEA KING HAR MK 3

Length • 57.5 feet (rotor folded)
Diameter of rotor • 62 feet
Maximum range • 306 miles
Weight empty • 12,980 pounds
Maximum speed • 155 mph

Tail rotor drive
The engine turns the tail rotor using a transmission rod that runs the length of the tail. A gearbox is needed wherever there is a bend in the transmission shaft.

Crane in the sky
The helicopter's winch enables it to lift survivors to safety. The winch is controlled from a panel alongside the door. There is usually room for 11 seated passengers and three stretcher passengers inside the *Sea King*.

Winch operator
After guiding the helicopter to its target, the radar operator takes on the job of winch operator. By giving instructions to the pilot over an intercom, the winch operator maneuvers the helicopter to exactly the right position before lowering the winchman on the end of the cable.

Tail rotor
Every helicopter has at least two rotors. If a helicopter had only one rotor, it would spin around in the opposite direction to the rotor blades as soon as it left the ground. The tail rotor stops this from happening by pushing the tail sideways.

Radar scanner
The helicopter's radar system enables the crew to locate their target in the dark or in thick fog.

UHF antenna
The crew keeps in touch with their base using UHF radio.

Blade pitch change mechanism
By altering the pitch of the tail rotor, the pilot can turn the helicopter in the air.

Collapsible copter
The tail of the helicopter is hinged so that it can be stowed in a small space.

Transponder
Like all aircraft, the *Sea King* has an automatic transponder. When radar waves from a nearby aircraft hit the transponder, it sends out a unique "Interrogation Friend or Foe" signal, which identifies the helicopter.

Floating flyer
The *Sea King* often carries out rescues over water, so it has a boat-shaped hull and can stay afloat on a calm sea.

RAF *Sea King* HAR Mk3

The Westland *Sea King* HAR Mk3 is adapted from a Sikorsky helicopter that was first used for antisubmarine warfare in the United States. In the air-sea rescue version of the helicopter, medical supplies and stretchers take the place of rockets and depth charges. The helicopter's bright yellow paintwork makes it easy to spot as it approaches a disaster at sea.

Tail wheel
A non-retractable tail wheel provides a soft and stable landing for the helicopter.

Life line
The winchman's life depends on the steel winch cable, so the cable is checked carefully after every mission.

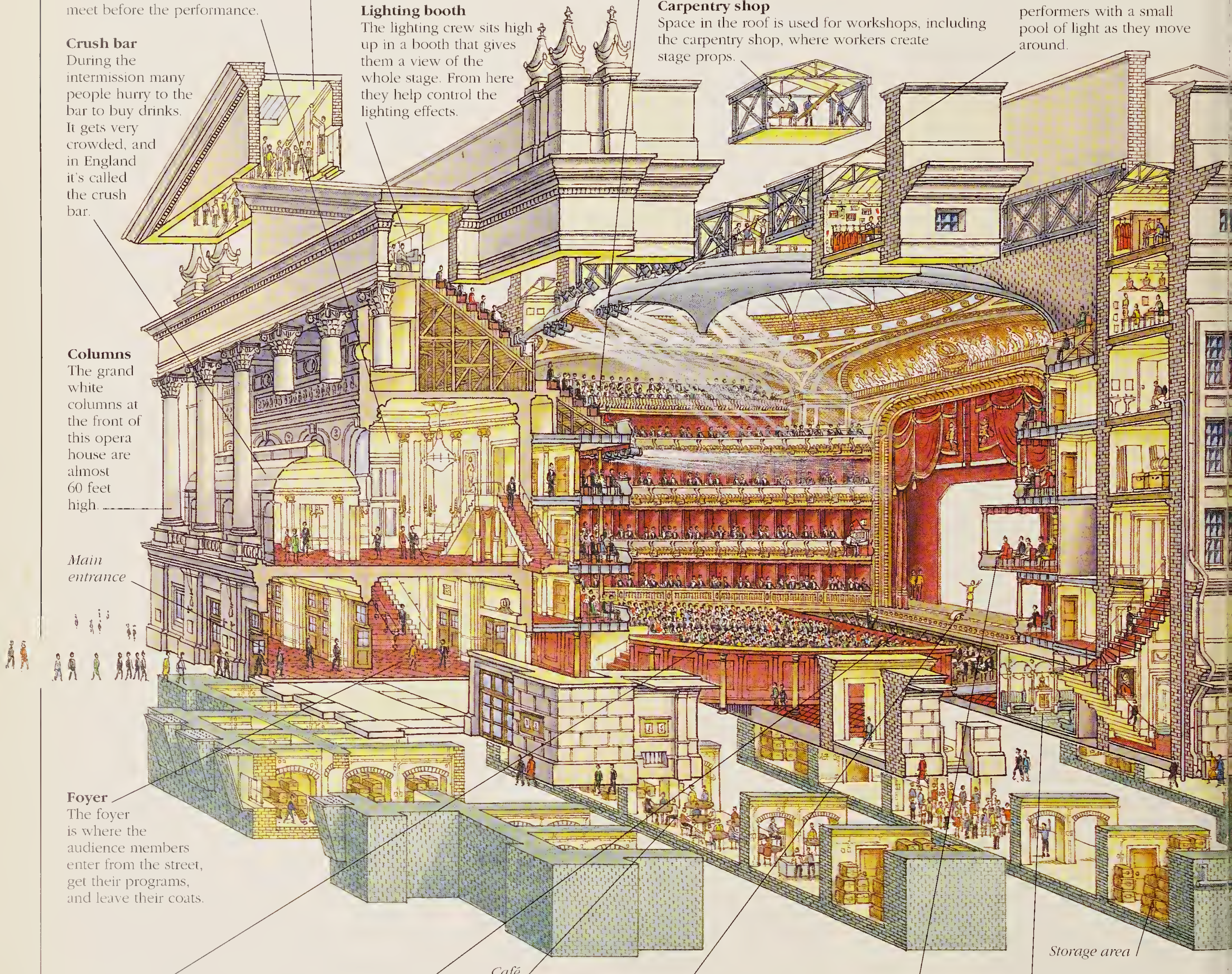
Stretcher
Badly injured survivors are lifted using the Neil Robertson stretcher, named after its inventor. It has fabric flaps lined with wooden splints which keep the survivor's body immobile.

Winchman
Dangling on the end of the winch cable, the winchman is the most visible crew member. He picks up the survivors, often from the deck of a ship that may be pitching wildly in rough seas.

OPERA HOUSE

When you step inside an opera house, you leave reality behind. Like a magic spell, the action on the stage transports you to another land, another time, another world. From the auditorium (the area where you sit and watch), operatic productions seem effortless, graceful, and glamorous. But the glitter of the stage is a beautiful and pleasant illusion.

Keeping up the illusion is hard work. An operatic production involves many singers and instrumentalists and can include dancers and extras. There is also an army of other workers who make and paint sets, sew costumes, and sell tickets. All day long around the building the magic spell of opera is created with paint, cloth, wood, sheets of music, and hours of rehearsal.



Meet me in the saloon
Above the foyer (reception area) is a large, richly decorated room called the grand saloon in English opera houses. Here members of the audience can meet before the performance.

Rehearsal room
Every bit of space in the opera house is used as efficiently as possible. Here a rehearsal room is tucked in behind the pediment – the triangular portion under the roof.

Opera for everyone
The cheapest seats, called the slips, are at the very top of the theater and in the far corners. . The view is not very good, but the price is low.

Spotlights
Powerful spotlights pick out individual performers on the stage. By turning the lamps, the lighting technicians can follow the performers with a small pool of light as they move around.

Lighting booth
The lighting crew sits high up in a booth that gives them a view of the whole stage. From here they help control the lighting effects.

Carpentry shop
Space in the roof is used for workshops, including the carpentry shop, where workers create stage props.

Crush bar
During the intermission many people hurry to the bar to buy drinks. It gets very crowded, and in England it's called the crush bar.

Columns
The grand white columns at the front of this opera house are almost 60 feet high.

Foyer
The foyer is where the audience members enter from the street, get their programs, and leave their coats.

Orchestra
The most expensive seats in the opera house are the orchestra. But here you get the best view, and you can hear the music better than anywhere else in the auditorium.

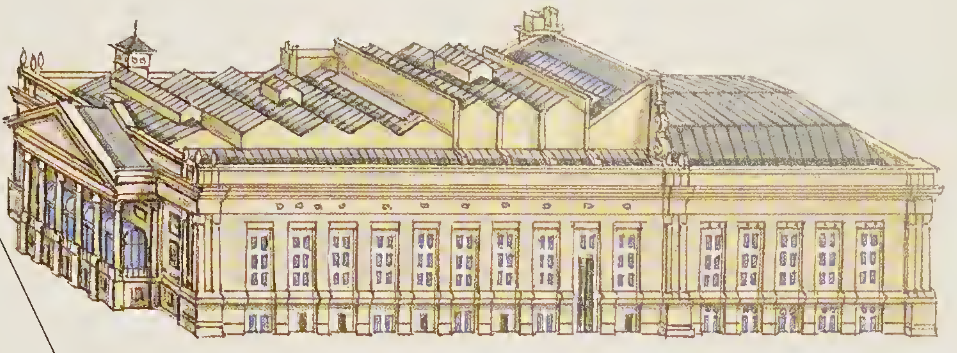
Orchestra pit
The musicians sit between the stage and the audience, in the orchestra pit. They face the conductor, who uses gestures to lead both the musicians in the pit and the performers on the stage.

What's my line?
In the center of the stage is the prompt booth, where the prompter follows the words of the opera from a score (the words and music of the opera). If singers forget their words, the prompter reminds them.

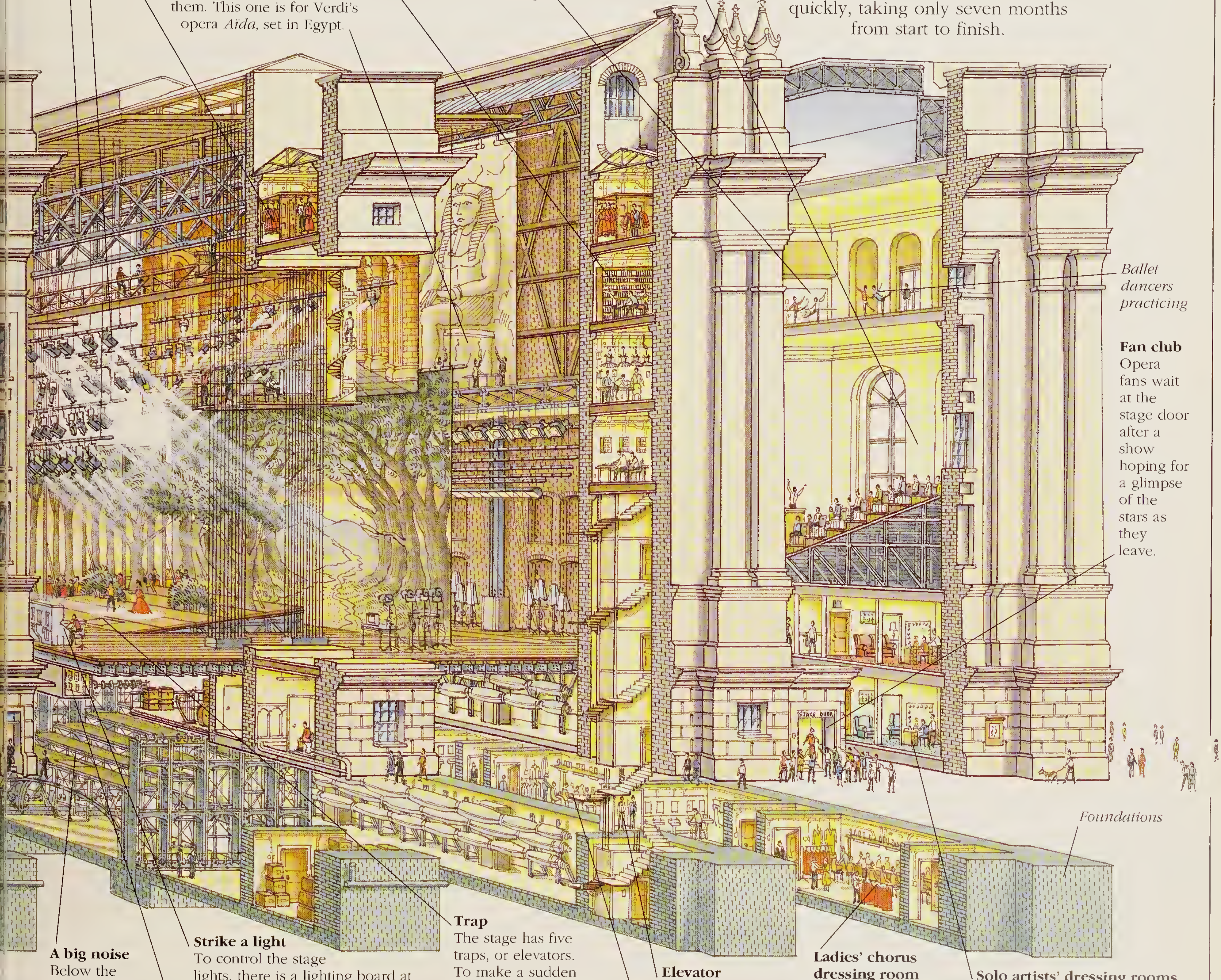
Royal box
In England, the best seats are reserved for the royal family. They are in a private box at the side of the stage.

Royal rooms
Royal visitors have a suite of rooms below their box, where they can sit in comfort before the performance and during the intermission.

ROYAL OPERA HOUSE, COVENT GARDEN



The Royal Opera House in London, England, is among the finest in the world. It is more than 130 years old, and was built to replace an older opera house on the same site that burned down in a fire. The building was completed quickly, taking only seven months from start to finish.


Ballet dancers practicing
Foundations
Gentlemen's chorus dressing room

A supporting role
Eight huge girders support the roof. Each weighs 33 tons. The girders were prefabricated (constructed separately from the rest of the building) in a factory 100 miles from the opera house.

Lighting
Powerful lamps hang from gantries (long hanging racks) above the stage.

Costume storeroom
Designing and making costumes is a huge task: everybody in the cast has at least one costume.

Painting room
Because backdrops are so big, there is a huge room for painting them. This one is for Verdi's opera *Aida*, set in Egypt.

Chorus rehearsal room
A choir, called the chorus, sing some of the opera by themselves, and sometimes accompany the opera soloists. The chorus practices in a large room at the back of the building.

Score storeroom
Every member of the cast needs a copy of the score, and there is a different part for each musical instrument in the orchestra. So the opera house has a library containing all the different parts for many operas.

Ballet practice room
The ballet dancers must practice for many hours each day. They have a rehearsal room high up behind the stage.

Fan club
Opera fans wait at the stage door after a show hoping for a glimpse of the stars as they leave.

A big noise
Below the stage is a large room where the orchestra rehearses, and where large instruments such as harps and pianos are stored.

Strike a light
To control the stage lights, there is a lighting board at the side of the stage. From here, the electricians can switch the lights on and off at the correct moment.

Switch room
The opera house uses a lot of electricity, and the switch room controls its distribution.

Trap
The stage has five traps, or elevators. To make a sudden appearance, a performer stands on a lowered trap beneath the stage. On cue (at the right instant in the production) stage hands operate the trap, and the performer is hoisted rapidly upward to stage level.

Elevator
The opera house is nine stories high, so an elevator is essential.

Ladies' chorus dressing room
The members of the chorus share a big dressing room. The costume staff has to start early in the day, washing, repairing, and pressing the many costumes.

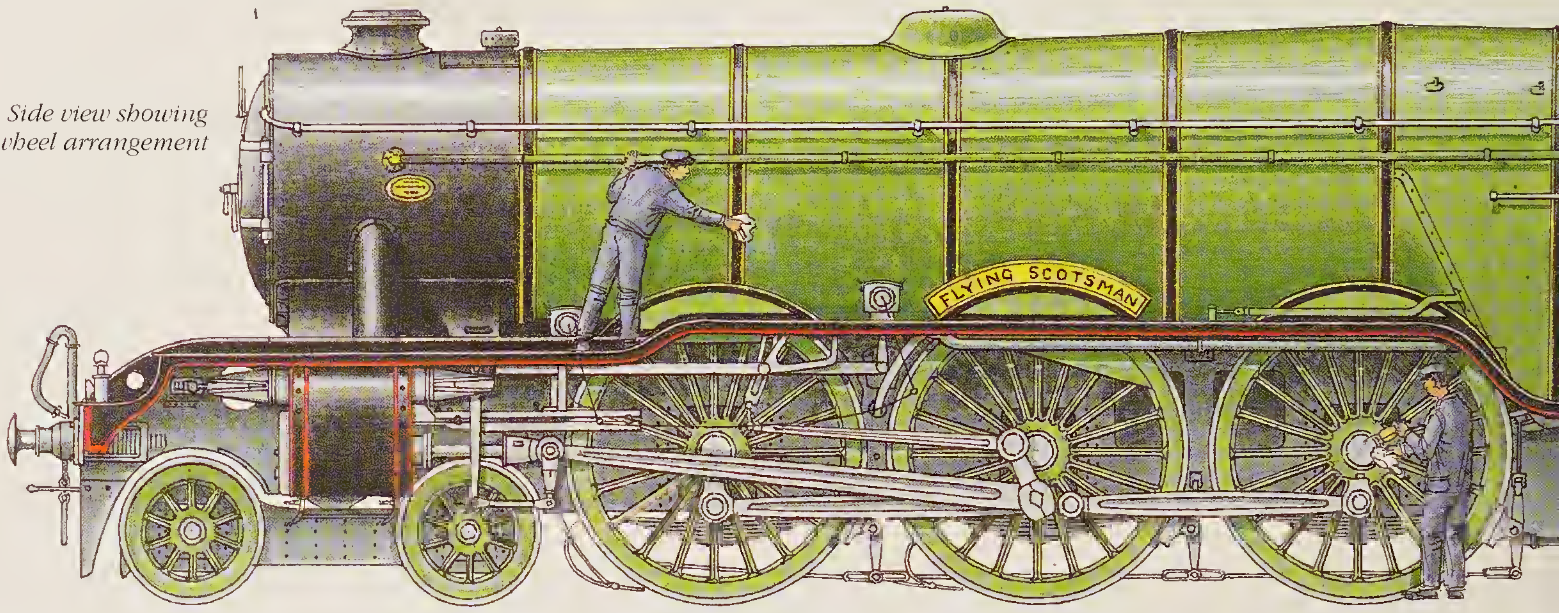
Solo artists' dressing rooms
Only the principals, or solo singers, have dressing rooms all to themselves. Most of the rooms are tiny, but well-known opera stars have a suite of rooms — a dressing room and a sitting room where they can entertain friends and fans.

STEAM TRAIN

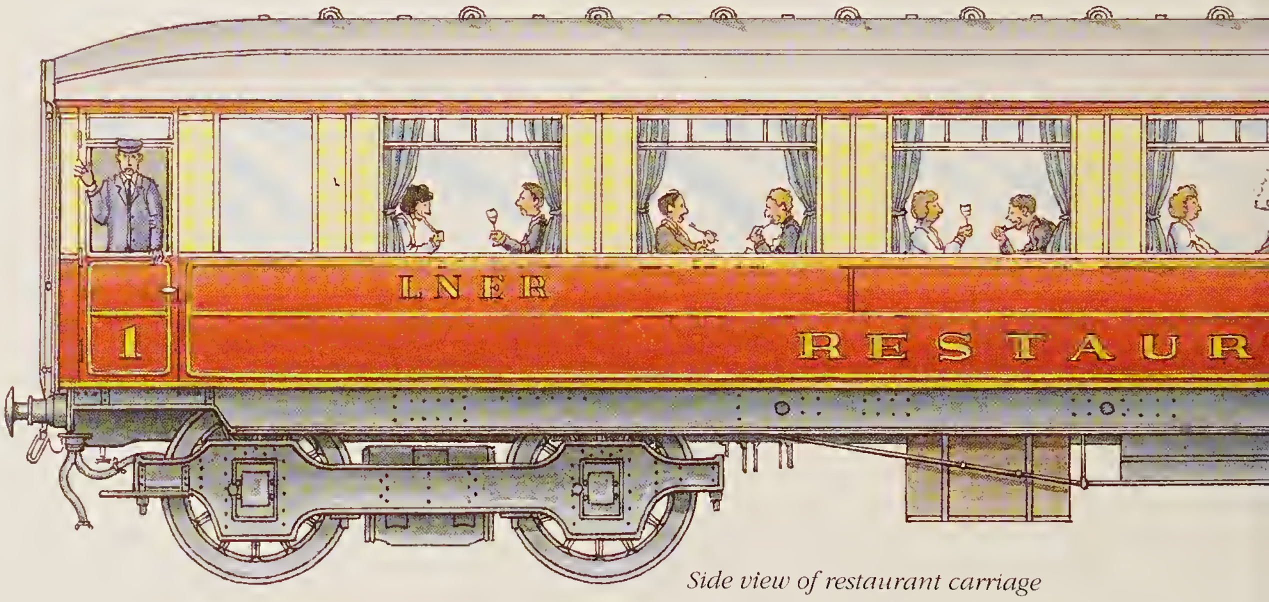
When steam trains first appeared, around 1830, they were the "new technology" of the age, as exciting as space travel is today. They terrified some people, who feared for their health if they traveled faster than a galloping horse. One writer commented: "What can be more ridiculous than locomotives traveling twice as fast as stagecoaches? We should as soon expect people to suffer themselves to be fired off on rockets as trust themselves to the mercy of a machine going at such a rate." Pleading for sanity, he demanded that railway trains be limited to a speed of eight or nine miles an hour. Others declared that locomotives would "cause the extinction of the race of horses." All these critics were proved wrong, and by the middle of the 20th century the steam train reigned as the most sophisticated method of land travel. Pullman passengers (those traveling in the most luxurious class) could enjoy an invigorating shower, a first-class meal, and the latest film in the train's movie theater.

LOCOMOTIVE

The locomotive shown here belonged to England's London and North Eastern Railway. It was numbered 4472 and named the *Flying Scotsman*. It is a "Pacific" class locomotive — a typical passenger express locomotive of the 1920s and 1930s. A Pacific class locomotive had six large driving wheels (three on each side), with four small wheels in front and two at the rear.



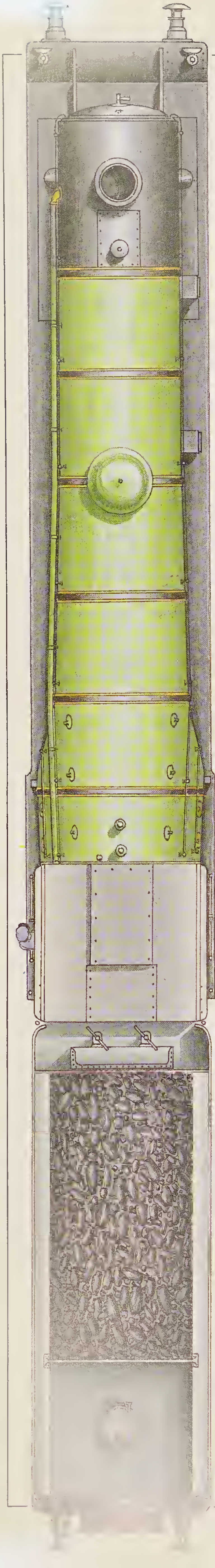
Side view showing wheel arrangement



Side view of restaurant carriage

BIRD'S-EYE VIEW

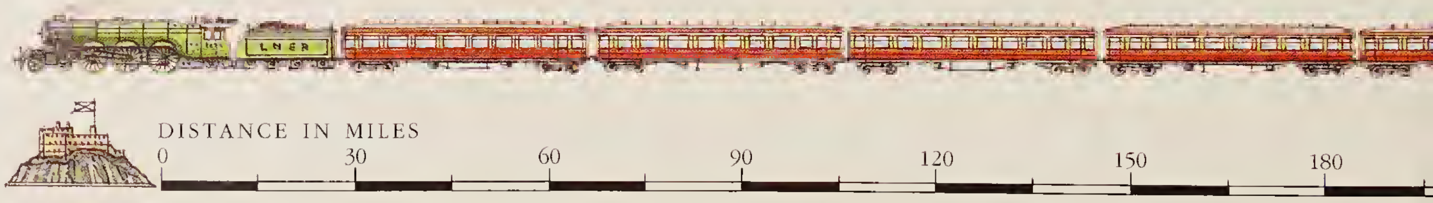
A torrent of steam and smoke usually hid the locomotive from view as it passed under a bridge. The tender held 10 tons of coal and nearly 5,000 gallons of water.



Top view of locomotive and tender

FLYING SCOTSMAN TRAIN

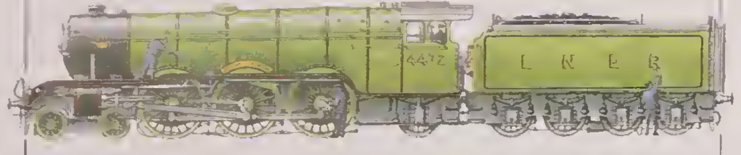
The *Flying Scotsman* was the name of both a locomotive and a train. The train traveled from London to Edinburgh, Scotland — a distance of 391 miles. Beginning in May 1928 it made the trip without stopping — at the time, the longest nonstop service in the world.



STEAM TRAIN

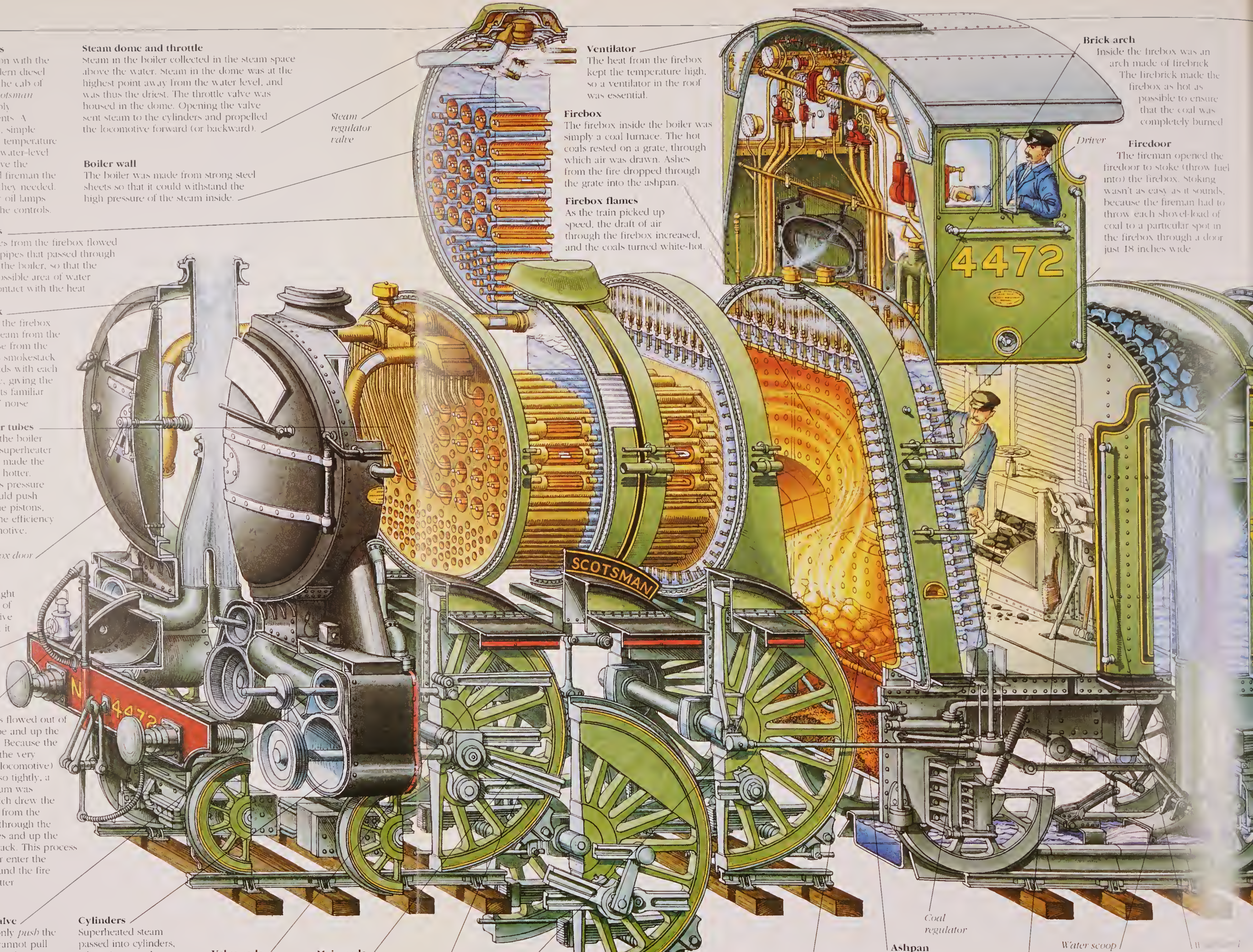
Breathing fire, steam, and smoke, a steam train was like a dragon on rails. To bring this dragon to life, though, required loving care, attention, and hard work. The crew at the roundhouse had to start work many hours before the train was due to depart. They lit a fire in the firebox, and when it was ablaze, they fed it with coal until the whole firebox was a roaring furnace. Gradually the heat warmed the water in the boiler which surrounded the firebox. As the water got hotter, it turned to steam. Each locomotive had a crew of two: an engineer, or driver, and a fireman. They took over from the roundhouse crew when it was time to drive the train. When the steam pressure was high enough, the engineer pulled back on the throttle, releasing steam into the locomotive's cylinders. The steam pressure forced the pistons back and forth, and the pistons turned the driving wheels linked to the pistons. Slowly the huge locomotive moved forward, puffing [illegible] of [illegible] of steam. Finally, with a shrill blast of the whistle, the locomotive moved off into the countryside, hauling up to 15 or 16 pullman cars at speeds up to 100 mph.

The 1930s were golden years of steam railway travel in Great Britain; gorgeously painted locomotives such as the London and North Eastern Railway's *Flying Scotsman*, shown here, pulled luxurious cars nonstop over great distances. Eventually, though, cheap road and air travel made the costs of running such lavish trains too great. This, and the expense of fighting World War II (1939-1945), meant that such passenger luxury was only rarely, if ever, seen again.



FLYING SCOTSMAN

The *Flying Scotsman* locomotive shown here was designed by Sir Nigel Gresley (1876-1941). Gresley designed several famous locomotives for the London and North Eastern Railway. Number 4472 was part of a class of locomotive that dated from 1923. One of Gresley's later locomotives, the *Mallard* (No. 4468), still holds the speed record for a steam locomotive — 125 mph — reached in a test run in 1938. Both *Flying Scotsman* and *Mallard* are preserved today.



Cab controls
By comparison with the cab of a modern diesel locomotive, the cab of the *Flying Scotsman* has remarkably few instruments. A speedometer, simple pressure and temperature gauges, and water-level indicators gave the engineer and fireman the information they needed. At night, tiny oil lamps illuminated the controls.

Steam dome and throttle
Steam in the boiler collected in the steam space above the water. Steam in the dome was at the highest point away from the water level, and was thus the driest. The throttle valve was housed in the dome. Opening the valve sent steam to the cylinders and propelled the locomotive forward (or backward).

Boiler wall
The boiler was made from strong steel sheets so that it could withstand the high pressure of the steam inside.

Boiler tubes
Hot flue gases from the firebox flowed along many pipes that passed through the water in the boiler, so that the maximum possible area of water came into contact with the heat

Smokestack
Smoke from the firebox and waste steam from the cylinders rose from the locomotive's smokestack in great clouds with each piston stroke, giving the locomotive its familiar "chuff-chuff" noise

Superheater tubes
Steam from the boiler passed into superheater tubes which made the steam much hotter, increasing its pressure so that it could push harder on the pistons, improving the efficiency of the locomotive.

Light
A warning light on the front of the locomotive ensured that it was visible at night.

Blast pipe
Steam from the cylinders flowed out of the blast pipe and up the smokestack. Because the smokebox (the very front of the locomotive) was closed so tightly, a partial vacuum was created, which drew the waste gases from the firebox through the fire tubes and up the smokestack. This process made air enter the firebox and the fire burn hotter

Cylinder valve
Steam can only *push* the cylinder, it cannot pull it. So to make the cylinder oscillate (move alternately backward and forward), an arrangement of valves let the steam flow into the cylinder first at one side of the piston and then at the other.

Cylinders
Superheated steam passed into cylinders, where it pressed on pistons which drove the wheels via connecting rods. On the *Flying Scotsman* there were three cylinders: one on each side, and a third cylinder between the wheels.

Valve rods
Another set of rods coordinated the opening and closing of the valves that controlled the flow of steam into the cylinders.

Main rods
Heavy steel rods transferred the movement of the pistons to the wheels that drove the locomotive forward.

Side rods
Usually there was more than one pair of driving wheels; coupling rods connected the driving wheels together so that they all turned in unison.

Brakes
Operating the brakes pressed a steel block against the wheel, slowing the train.

Grate
The bars of the grate kept unburned coal from falling out of the firebox and allowed air to flow in from below.

Ashpan
When the coal in the firebox had completely burned, the remaining ash dropped into the ashpan. One of the fireman's jobs was to empty the ashpan: a task that often covered him in hot ash.

Water pickup tap
To take on water without stopping, the [illegible] *Scotsman* tender had a water scoop. Th[illegible] lowered the scoop as the train approa[illegible] water trough. The forward motion of th[illegible] forced water up the pickup spout from [illegible] trough between the rails, and it splashed down into the tank inside the tender

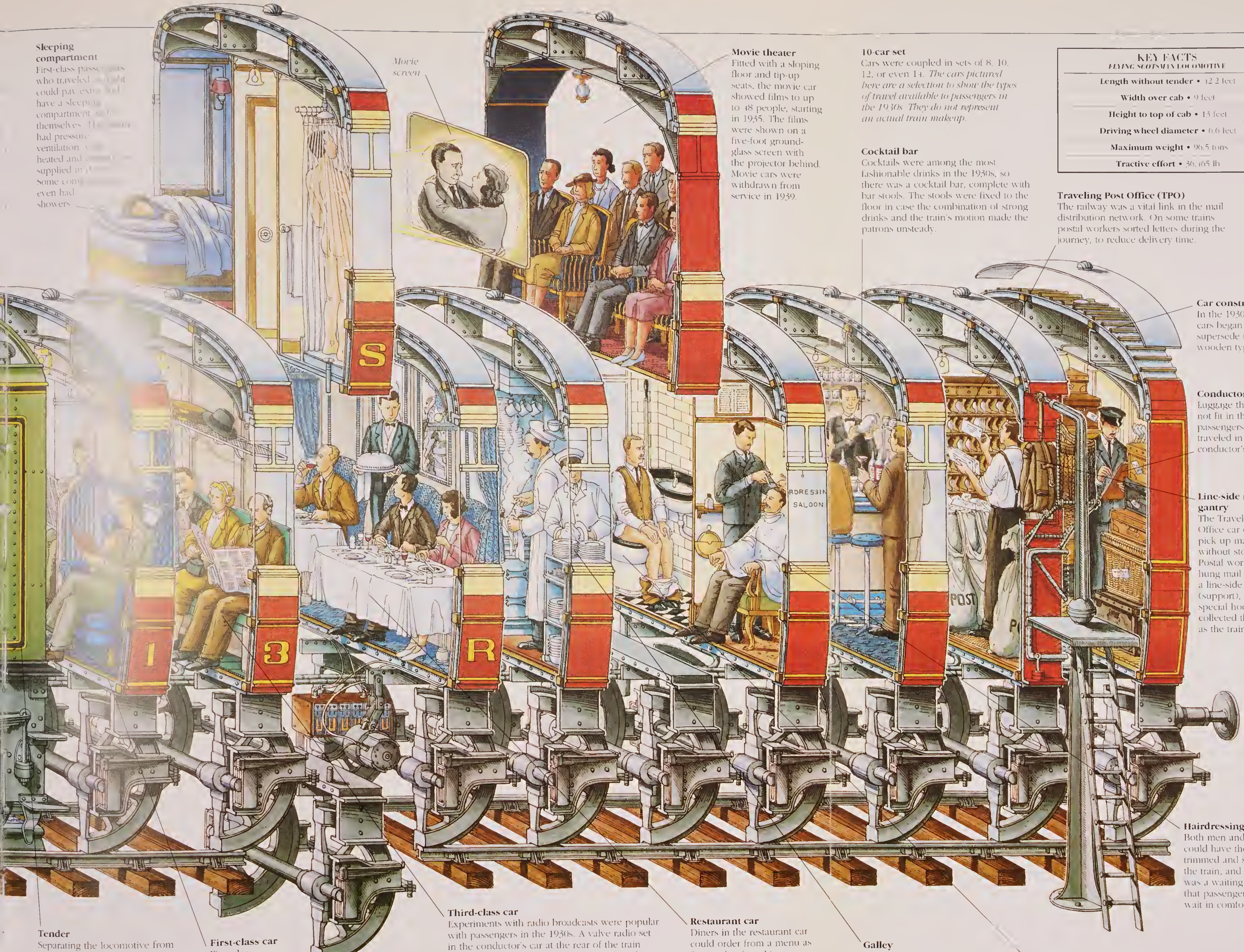
Ventilator
The heat from the firebox kept the temperature high, so a ventilator in the roof was essential.

Firebox
The firebox inside the boiler was simply a coal furnace. The hot coals rested on a grate, through which air was drawn. Ashes from the fire dropped through the grate into the ashpan.

Firebox flames
As the train picked up speed, the draft of air through the firebox increased, and the coals turned white-hot.

Brick arch
Inside the firebox was an arch made of firebrick. The firebrick made the firebox as hot as possible to ensure that the coal was completely burned

Firedoor
The fireman opened the firedoor to stoke (throw fuel into) the firebox. Stoking wasn't as easy as it sounds, because the fireman had to throw each shovel-load of coal to a particular spot in the firebox through a door just 18 inches wide



Sleeping compartment
First-class passengers who traveled at night could pay extra [illegible] have a sleeping compartment [illegible] themselves. [illegible] had pressure [illegible] ventilation [illegible] heated and [illegible] supplied in [illegible] Some com[illegible] even had showers

Movie theater
Fitted with a sloping floor and tip-up seats, the movie car showed films to up to 48 people, starting in 1935. The films were shown on a five-foot ground-glass screen with the projector behind. Movie cars were withdrawn from service in 1939.

10-car set
Cars were coupled in sets of 8, 10, 12, or even 14. *The cars pictured here are a selection to show the types of travel available to passengers in the 1930s. They do not represent an actual train makeup.*

Cocktail bar
Cocktails were among the most fashionable drinks in the 1930s, so there was a cocktail bar, complete with bar stools. The stools were fixed to the floor in case the combination of strong drinks and the train's motion made the patrons unsteady.

KEY FACTS
***FLYING SCOTSMAN* LOCOMOTIVE**

Length without tender • 12.2 feet

Width over cab • 9 feet

Height to top of cab • 13 feet

Driving wheel diameter • 6.6 feet

Maximum weight • 96.5 tons

Tractive effort • 36,465 lb

Traveling Post Office (TPO)
The railway was a vital link in the mail distribution network. On some trains postal workers sorted letters during the journey, to reduce delivery time.

Car construction
In the 1930s steel cars began to supersede the older wooden types.

Conductor's car
Luggage that did not fit in the passengers' cars traveled in the conductor's car.

Line-side mail gantry
The Traveling Post Office car could pick up mailbags without stopping. Postal workers hung mail bags on a line-side gantry (support), and a special hook collected the bags as the train passed.

Hairdressing salon
Both men and women could have their hair trimmed and styled on the train, and there was a waiting room so that passengers could wait in comfort.

Tender
Separating the locomotive from the rest of the train, the tender carried a supply of coal and water. The corridor tender on the *Flying Scotsman* was designed by Sir Nigel Gresley to go specifically with this locomotive.

First-class car
First-class compartments were more comfortable than third-class (there was no second class). In addition, they had other advantages, including "Vita-Glass," which "let through only the health-giving rays of the sun."

Third-class car
Experiments with radio broadcasts were popular with passengers in the 1930s. A valve radio set in the conductor's car at the rear of the train received radio programs and relayed them by cable to the cars. Passengers who wanted to listen wore headphones. Radio reception was impossible when the train passed through tunnels, and the conductor put on a record so that the music could continue.

Restaurant car
Diners in the restaurant car could order from a menu as fine as that found in many stationary restaurants. The tables had linen tablecloths, china plates, and real glasses, rather than the paper and plastic of the 1990s.

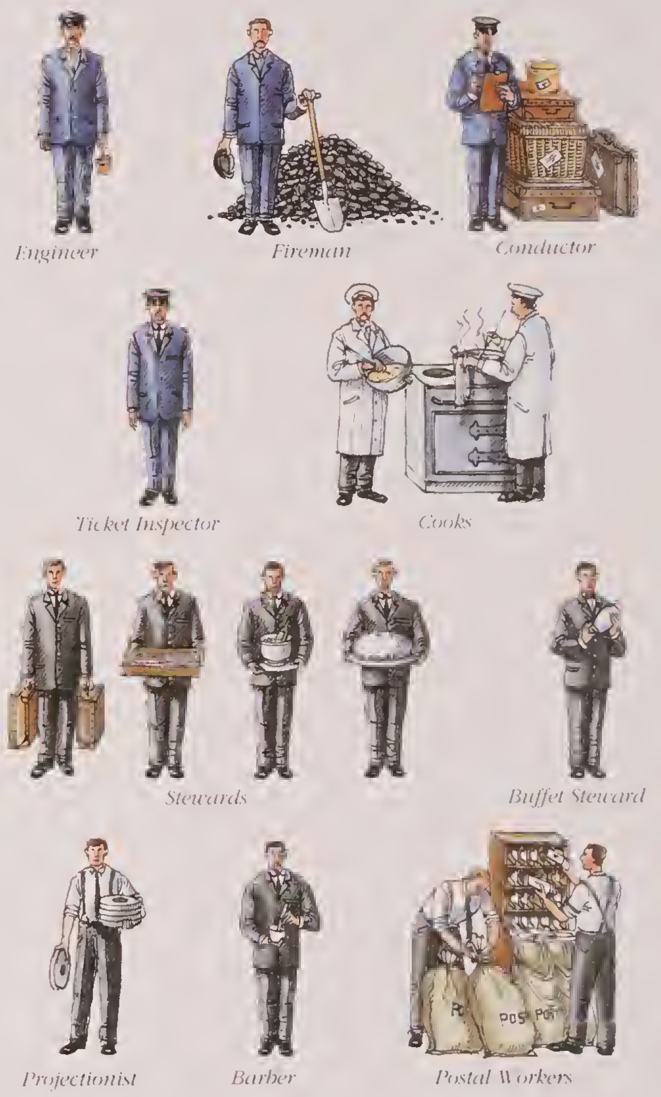
Galley
The cramped galley (kitchen) had an electric stove. However, the generators and batteries had limited capacity, so the roasting ovens were powered by a coal fire.

Lavatory
Flushing discharged the contents of the toilet bowl onto the track below, so maintenance workers walked alongside the rails, not between them.

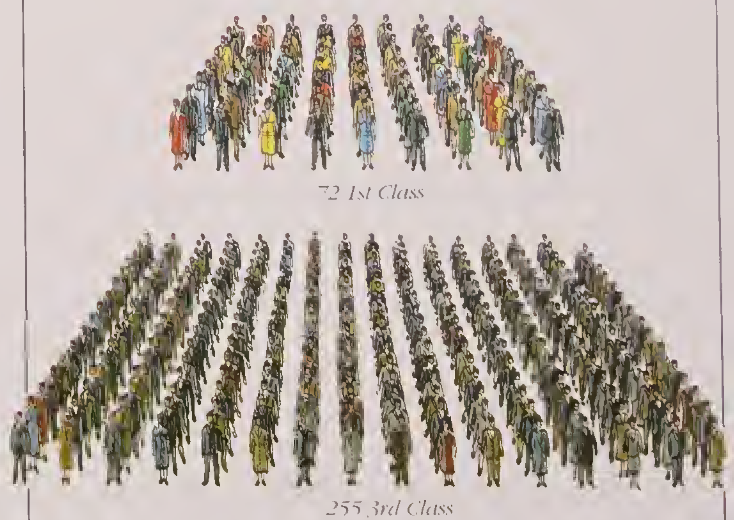
WHO WAS ON BOARD

Express trains in the 1930s had a large crew to look after the passengers' comfort and safety. The engineer and fireman drove the locomotive. The conductor looked after luggage and passenger safety. The ticket inspector made sure everyone traveled in the right class. Cooks prepared the meals; stewards served them. The barber looked after the passengers' hairdressing needs, and the projectionist showed films in the movie car. Finally, postal workers sorted mail in the TPO.

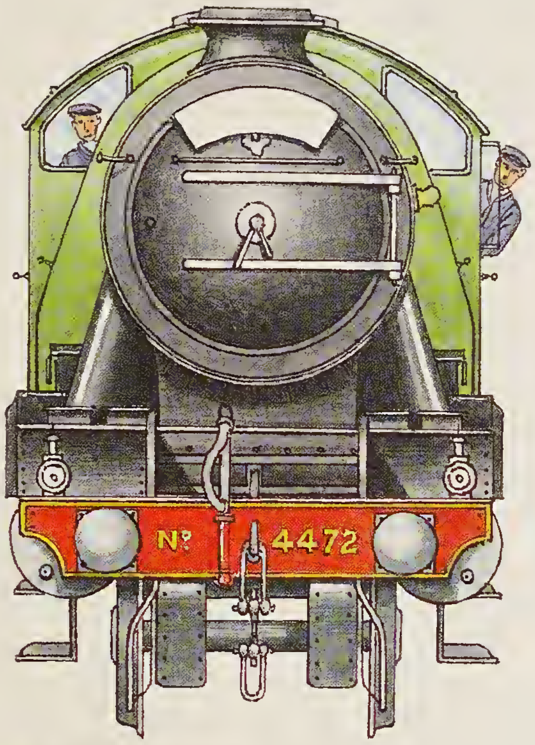
THE CREW



THE PASSENGERS



Front view showing smokebox door

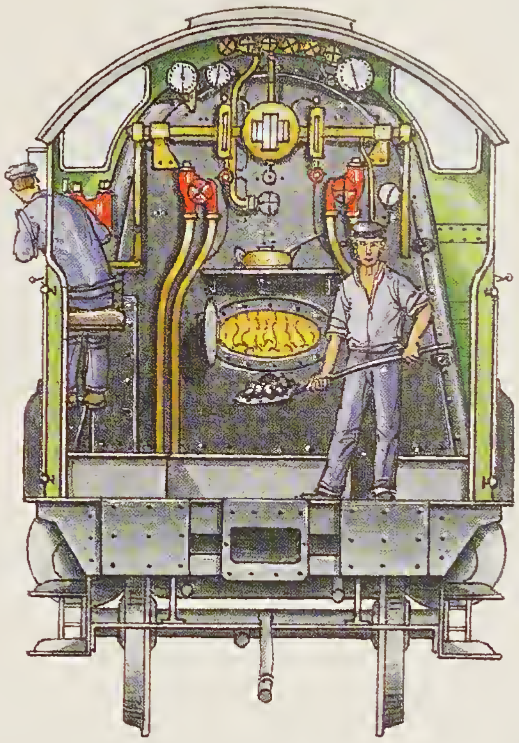


CAB

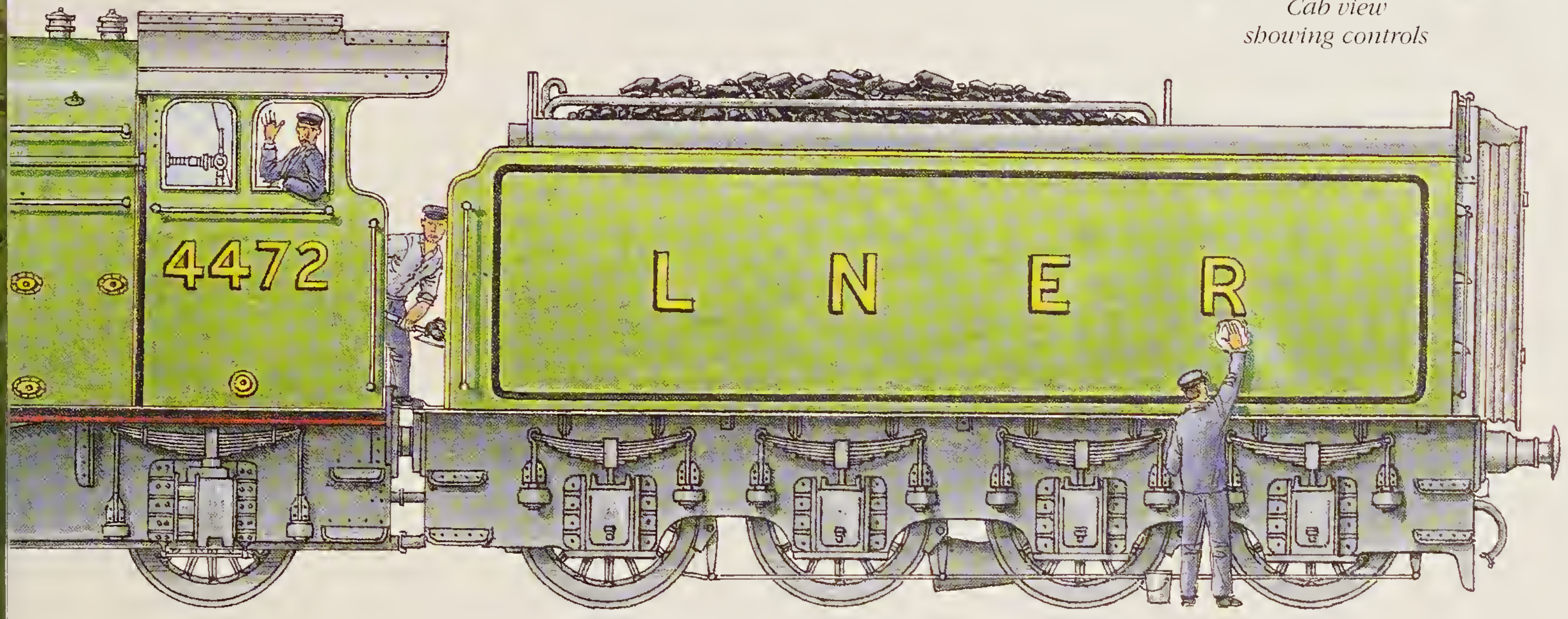
The controls of the locomotive were in the cab. The fireman fed the fire with coal. He had to learn the train's route so he would know when to stoke the fire to provide more power.

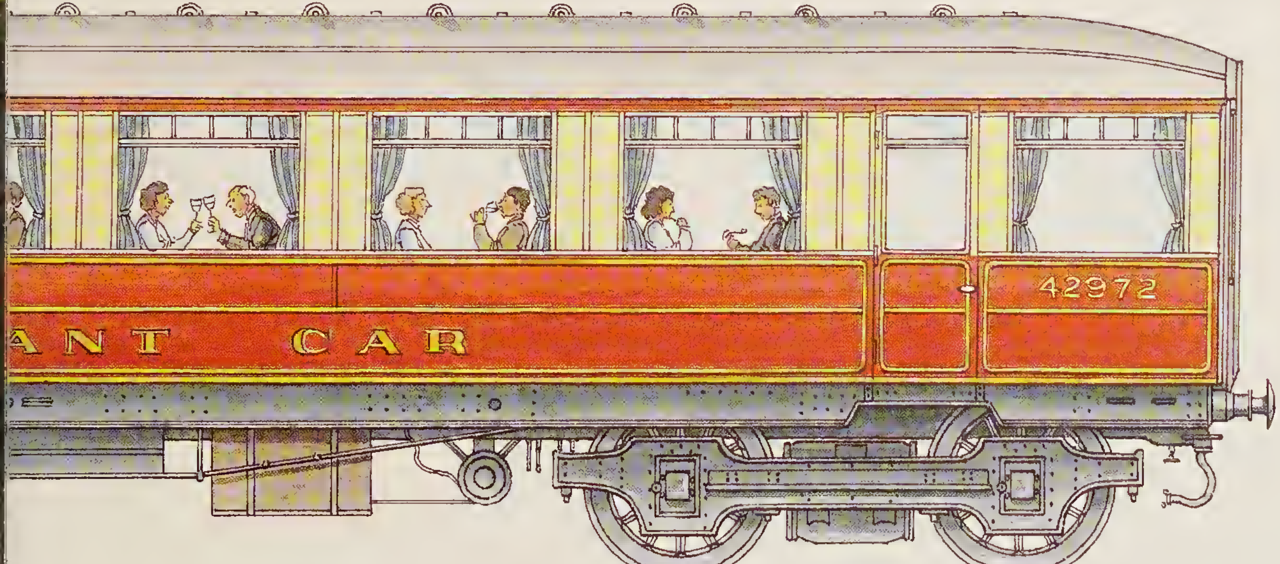
TENDER

Steam locomotives ran on coal (or oil) and water. The locomotive's tender carried a supply of both. The *Flying Scotsman*'s tender also had a corridor that allowed a relief crew to walk through and replace the engineer and fireman without stopping.



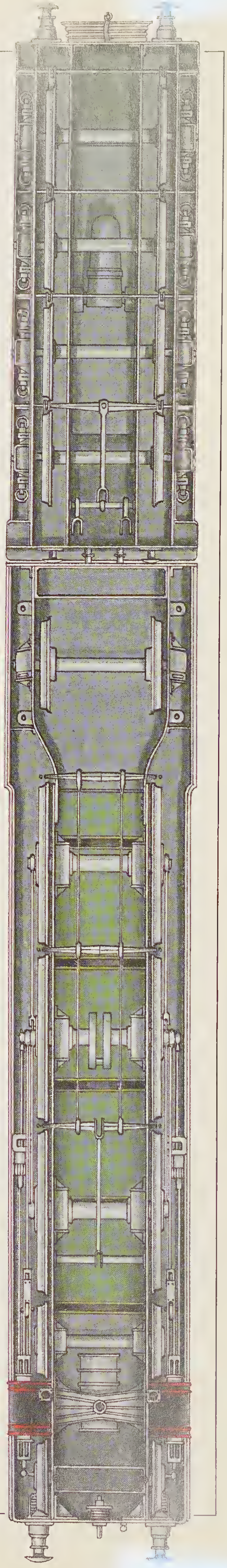
Cab view showing controls





LOOKING UP

This is the view that the maintenance crew had in the roundhouse when they crawled underneath the locomotive to make repairs.



Bottom view of locomotive and tender

RAILWAY CARS

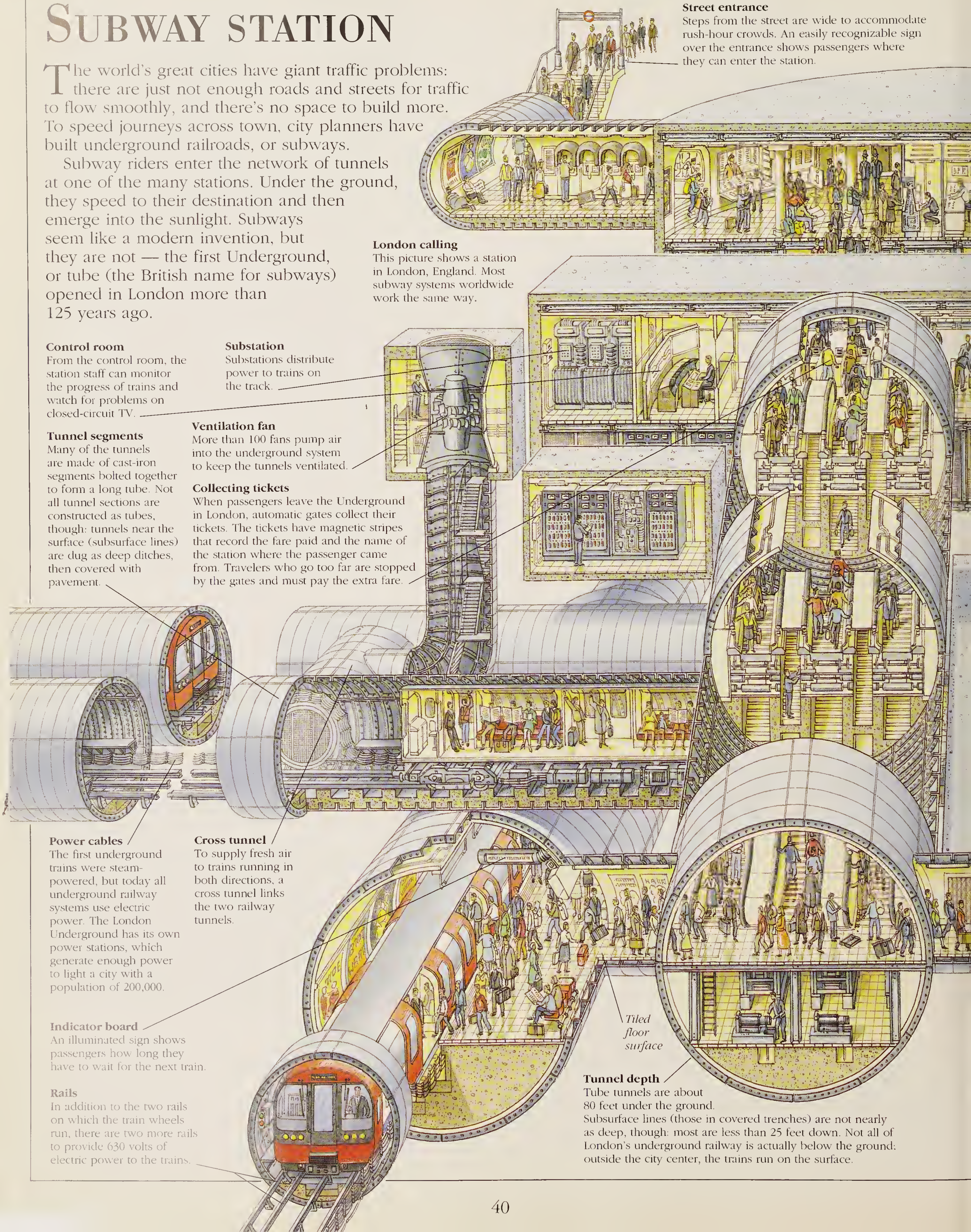
Railway cars were built by skilled workers, mainly using a framework of teakwood. By the 1930s, when the car shown above was built, many parts were made of steel. Some later steel-shelled cars were actually painted to look like teak!

210
240
270
300
330
360
390

SUBWAY STATION

The world's great cities have giant traffic problems: there are just not enough roads and streets for traffic to flow smoothly, and there's no space to build more. To speed journeys across town, city planners have built underground railroads, or subways.

Subway riders enter the network of tunnels at one of the many stations. Under the ground, they speed to their destination and then emerge into the sunlight. Subways seem like a modern invention, but they are not — the first Underground, or tube (the British name for subways) opened in London more than 125 years ago.



Street entrance
Steps from the street are wide to accommodate rush-hour crowds. An easily recognizable sign over the entrance shows passengers where they can enter the station.

London calling
This picture shows a station in London, England. Most subway systems worldwide work the same way.

Control room
From the control room, the station staff can monitor the progress of trains and watch for problems on closed-circuit TV.

Substation
Substations distribute power to trains on the track.

Tunnel segments
Many of the tunnels are made of cast-iron segments bolted together to form a long tube. Not all tunnel sections are constructed as tubes, though: tunnels near the surface (subsurface lines) are dug as deep ditches, then covered with pavement.

Ventilation fan
More than 100 fans pump air into the underground system to keep the tunnels ventilated.

Collecting tickets
When passengers leave the Underground in London, automatic gates collect their tickets. The tickets have magnetic stripes that record the fare paid and the name of the station where the passenger came from. Travelers who go too far are stopped by the gates and must pay the extra fare.

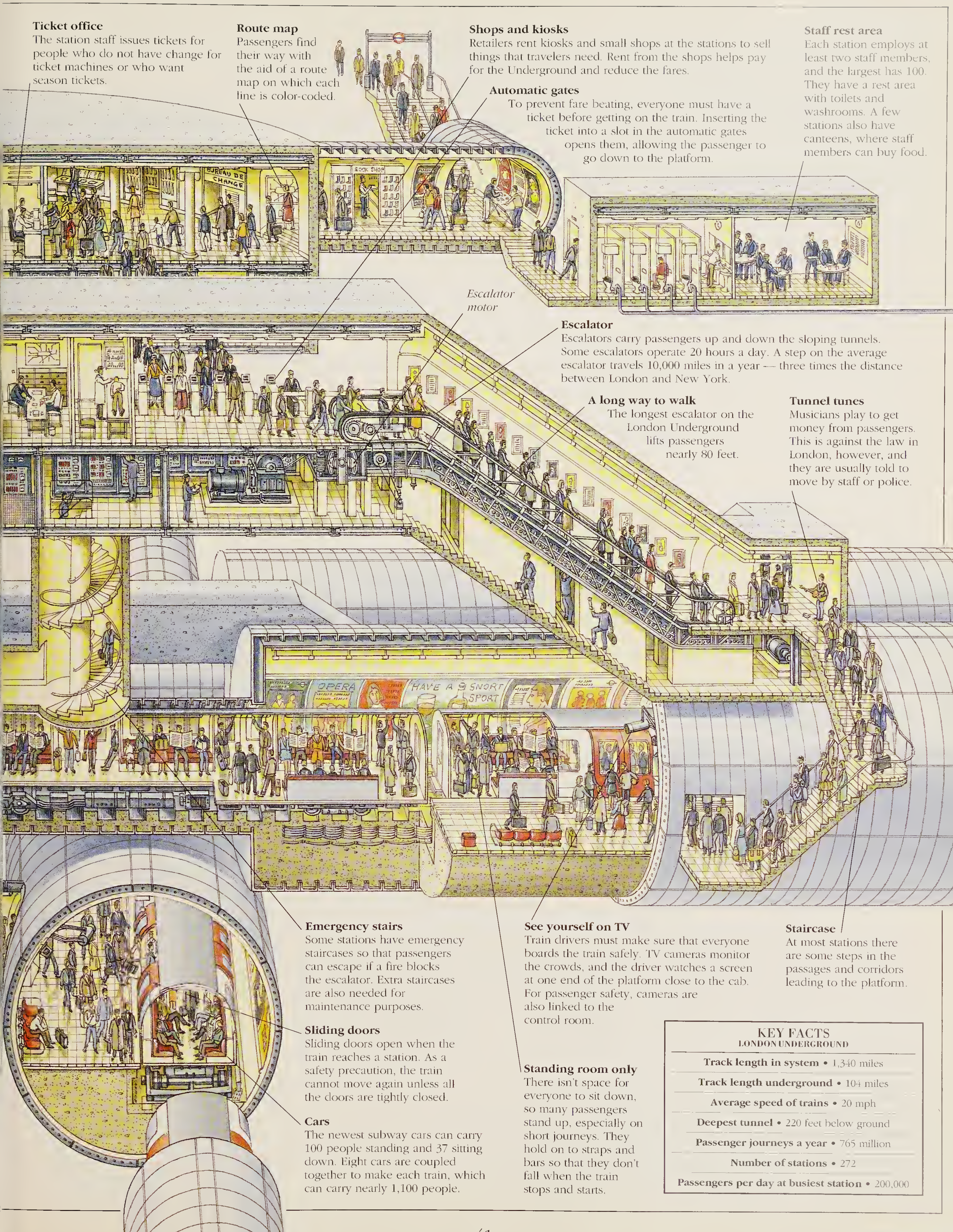
Power cables
The first underground trains were steam-powered, but today all underground railway systems use electric power. The London Underground has its own power stations, which generate enough power to light a city with a population of 200,000.

Cross tunnel
To supply fresh air to trains running in both directions, a cross tunnel links the two railway tunnels.

Indicator board
An illuminated sign shows passengers how long they have to wait for the next train.

Rails
In addition to the two rails on which the train wheels run, there are two more rails to provide 630 volts of electric power to the trains.

Tunnel depth
Tube tunnels are about 80 feet under the ground. Subsurface lines (those in covered trenches) are not nearly as deep, though: most are less than 25 feet down. Not all of London's underground railway is actually below the ground: outside the city center, the trains run on the surface.



Ticket office
The station staff issues tickets for people who do not have change for ticket machines or who want season tickets.

Route map
Passengers find their way with the aid of a route map on which each line is color-coded.

Shops and kiosks
Retailers rent kiosks and small shops at the stations to sell things that travelers need. Rent from the shops helps pay for the Underground and reduce the fares.

Automatic gates
To prevent fare beating, everyone must have a ticket before getting on the train. Inserting the ticket into a slot in the automatic gates opens them, allowing the passenger to go down to the platform.

Staff rest area
Each station employs at least two staff members, and the largest has 100. They have a rest area with toilets and washrooms. A few stations also have canteens, where staff members can buy food.

Escalator
Escalators carry passengers up and down the sloping tunnels. Some escalators operate 20 hours a day. A step on the average escalator travels 10,000 miles in a year — three times the distance between London and New York.

A long way to walk
The longest escalator on the London Underground lifts passengers nearly 80 feet.

Tunnel tunes
Musicians play to get money from passengers. This is against the law in London, however, and they are usually told to move by staff or police.

Emergency stairs
Some stations have emergency staircases so that passengers can escape if a fire blocks the escalator. Extra staircases are also needed for maintenance purposes.

Sliding doors
Sliding doors open when the train reaches a station. As a safety precaution, the train cannot move again unless all the doors are tightly closed.

Cars
The newest subway cars can carry 100 people standing and 37 sitting down. Eight cars are coupled together to make each train, which can carry nearly 1,100 people.

See yourself on TV
Train drivers must make sure that everyone boards the train safely. TV cameras monitor the crowds, and the driver watches a screen at one end of the platform close to the cab. For passenger safety, cameras are also linked to the control room.

Standing room only
There isn't space for everyone to sit down, so many passengers stand up, especially on short journeys. They hold on to straps and bars so that they don't fall when the train stops and starts.

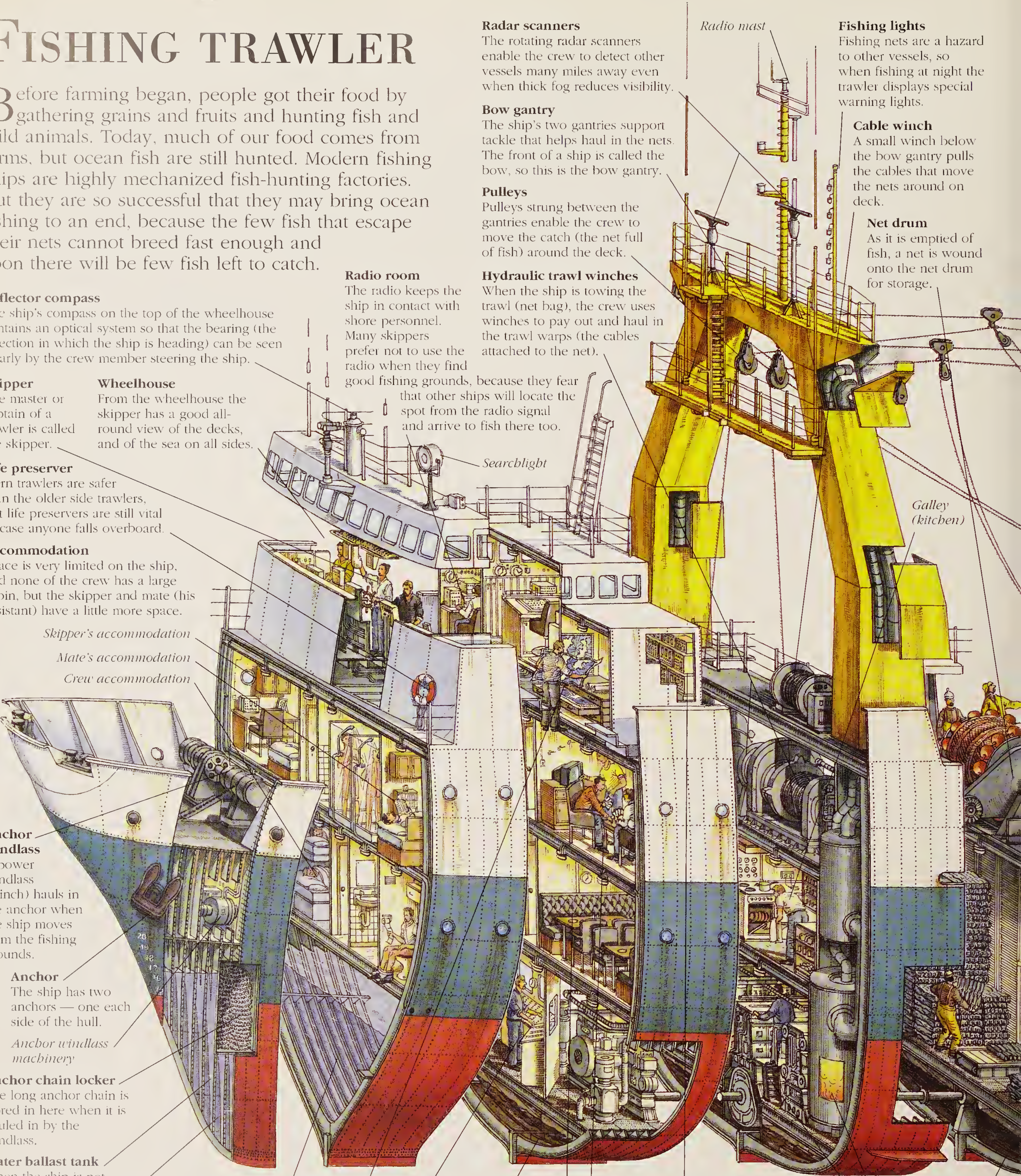
Staircase
At most stations there are some steps in the passages and corridors leading to the platform.

KEY FACTS
LONDON UNDERGROUND

Track length in system	1,340 miles
Track length underground	104 miles
Average speed of trains	20 mph
Deepest tunnel	220 feet below ground
Passenger journeys a year	765 million
Number of stations	272
Passengers per day at busiest station	200,000

FISHING TRAWLER

Before farming began, people got their food by gathering grains and fruits and hunting fish and wild animals. Today, much of our food comes from farms, but ocean fish are still hunted. Modern fishing ships are highly mechanized fish-hunting factories. But they are so successful that they may bring ocean fishing to an end, because the few fish that escape their nets cannot breed fast enough and soon there will be few fish left to catch.



Radar scanners
The rotating radar scanners enable the crew to detect other vessels many miles away even when thick fog reduces visibility.

Bow gantry
The ship's two gantries support tackle that helps haul in the nets. The front of a ship is called the bow, so this is the bow gantry.

Pulleys
Pulleys strung between the gantries enable the crew to move the catch (the net full of fish) around the deck.

Hydraulic trawl winches
When the ship is towing the trawl (net bag), the crew uses winches to pay out and haul in the trawl warps (the cables attached to the net).

Fishing lights
Fishing nets are a hazard to other vessels, so when fishing at night the trawler displays special warning lights.

Cable winch
A small winch below the bow gantry pulls the cables that move the nets around on deck.

Net drum
As it is emptied of fish, a net is wound onto the net drum for storage.

Radio room
The radio keeps the ship in contact with shore personnel. Many skippers prefer not to use the radio when they find good fishing grounds, because they fear that other ships will locate the spot from the radio signal and arrive to fish there too.

Reflector compass
The ship's compass on the top of the wheelhouse contains an optical system so that the bearing (the direction in which the ship is heading) can be seen clearly by the crew member steering the ship.

Skipper
The master or captain of a trawler is called the skipper.

Wheelhouse
From the wheelhouse the skipper has a good all-round view of the decks, and of the sea on all sides.

Life preserver
Stern trawlers are safer than the older side trawlers, but life preservers are still vital in case anyone falls overboard.

Accommodation
Space is very limited on the ship, and none of the crew has a large cabin, but the skipper and mate (his assistant) have a little more space.

Anchor windlass
A power windlass (winch) hauls in the anchor when the ship moves from the fishing grounds.

Anchor
The ship has two anchors — one each side of the hull.

Anchor chain locker
The long anchor chain is stored in here when it is hauled in by the windlass.

Water ballast tank
When the ship is not fully loaded, water in the ballast tank keeps it on an even keel (level in the sea). As the crew catches and loads fish, water is pumped out of the ballast to compensate for the extra weight on board.

Rib construction
The ship must be strong to withstand the ice and high seas of the Arctic fishing grounds. So the steel plates of the hull are welded to a structure of ribs.

Chart room
Ocean maps are called charts. They show the coastline, water depth, and features such as lighthouses.

Engine control room
Insulation absorbs the noise from the engines, so the control room is fairly quiet.

Messroom
The crew eats in the messroom during breaks in the fishing.

Electronics room
Fishing vessels have many navigational aids. Electronic instruments monitor signals from land beacons or orbiting satellites to give the ship's position to within about 300 feet. Sonar and echo sounding equipment help the crew locate schools of fish.

Engine room
The 2,500-horsepower main engine can power the ship forward at up to 14 knots (16 mph).

Fishing Trawler

KEY FACTS

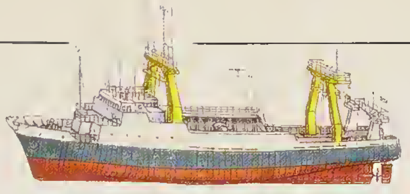
Length • 197 feet

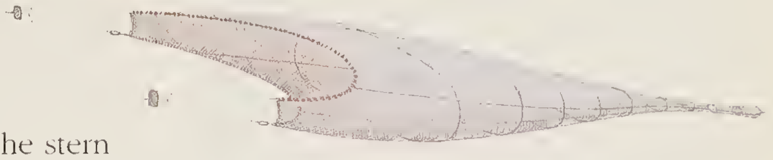
Breadth • 38 feet

Weight • 1,034 tons

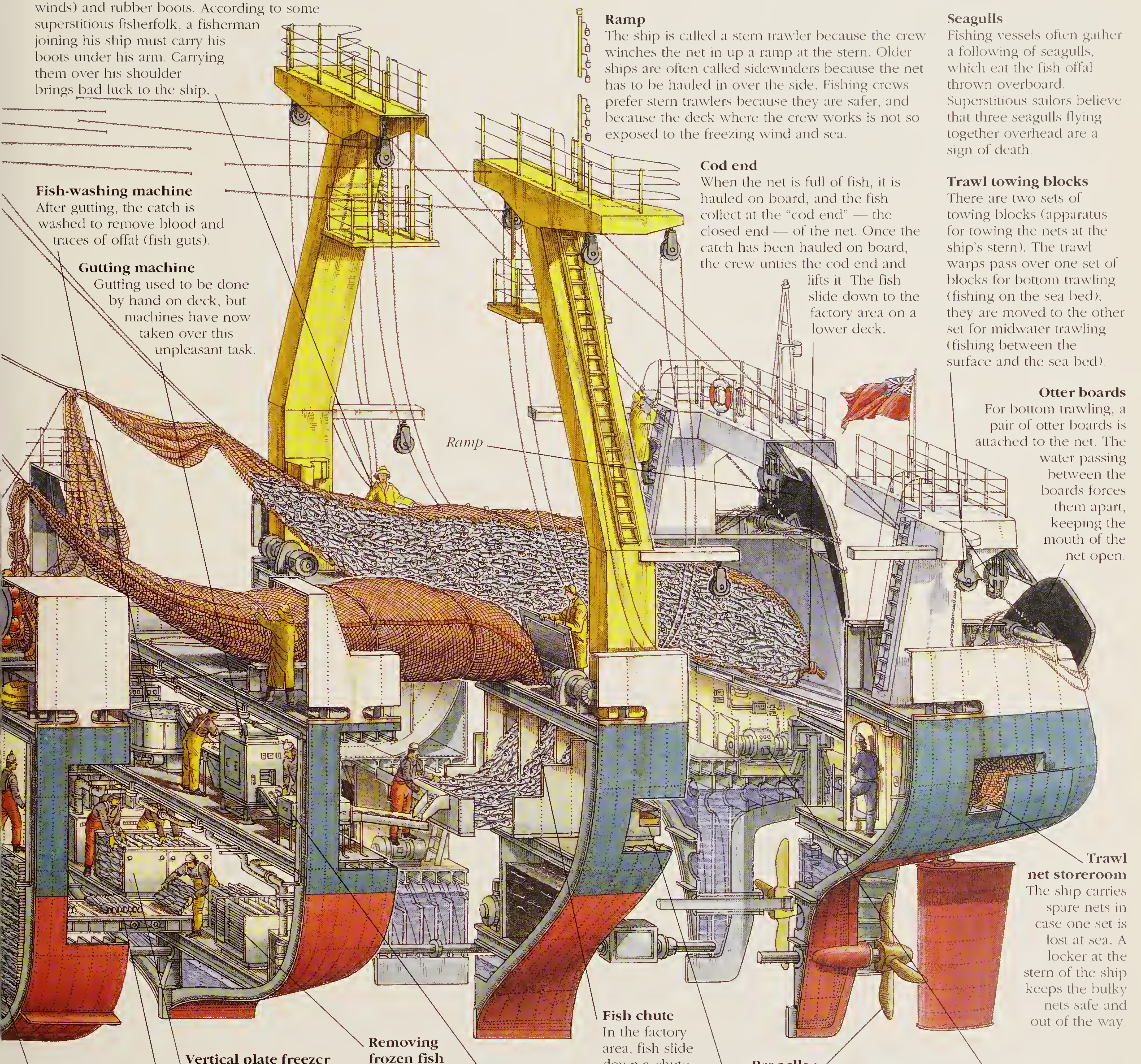
Freezing capacity • 27.5 tons/day

Hold capacity • 660 tons





Trawlers fish by towing a net bag, or trawl, behind them as they move forward through the water. The stern trawler, shown here, developed in the 1950s from the whaling ship which had ramps at the stern (rear) to haul whale carcasses on board. On-board freezing plants, which became commonplace in the 1960s, made it possible for fishing vessels to make longer trips because the frozen catch did not spoil at sea.



Deck hands
On deck crew members wear waterproof coats and hats (called sou'westers after the cold southwesterly winds) and rubber boots. According to some superstitious fisherfolk, a fisherman joining his ship must carry his boots under his arm. Carrying them over his shoulder brings bad luck to the ship.

Fish-washing machine
After gutting, the catch is washed to remove blood and traces of offal (fish guts).

Gutting machine
Gutting used to be done by hand on deck, but machines have now taken over this unpleasant task.

Ramp
The ship is called a stern trawler because the crew winches the net in up a ramp at the stern. Older ships are often called sidewinders because the net has to be hauled in over the side. Fishing crews prefer stern trawlers because they are safer, and because the deck where the crew works is not so exposed to the freezing wind and sea.

Cod end
When the net is full of fish, it is hauled on board, and the fish collect at the "cod end" — the closed end — of the net. Once the catch has been hauled on board, the crew unties the cod end and lifts it. The fish slide down to the factory area on a lower deck.

Seagulls
Fishing vessels often gather a following of seagulls, which eat the fish offal thrown overboard. Superstitious sailors believe that three seagulls flying together overhead are a sign of death.

Trawl towing blocks
There are two sets of towing blocks (apparatus for towing the nets at the ship's stern). The trawl warps pass over one set of blocks for bottom trawling (fishing on the sea bed); they are moved to the other set for midwater trawling (fishing between the surface and the sea bed).

Otter boards
For bottom trawling, a pair of otter boards is attached to the net. The water passing between the boards forces them apart, keeping the mouth of the net open.

Trawl net storeroom
The ship carries spare nets in case one set is lost at sea. A locker at the stern of the ship keeps the bulky nets safe and out of the way.

Fish chute
In the factory area, fish slide down a chute onto a conveyor.

Fish hold
At the heart of the ship is the fish hold, a giant cold storage that keeps the catch frozen in solid blocks at -4°F for transport back to the shore.

Vertical plate freezer
The ship's freezer freezes fish into blocks weighing about 110 pounds. It can handle about 27 tons a day.

Conveyor
Frozen fish blocks move from the factory area to the fish hold along a conveyor.

Removing frozen fish
Freezing takes about an hour, then the crew removes the solid blocks of fish and loads them onto the conveyor leading to the fish hold.

Deheading machine
Fish to be sold at fish stores is frozen whole, but much of the catch will go for processing into prepared fish products. To save space in storage, these fish have their heads removed at the start of processing.

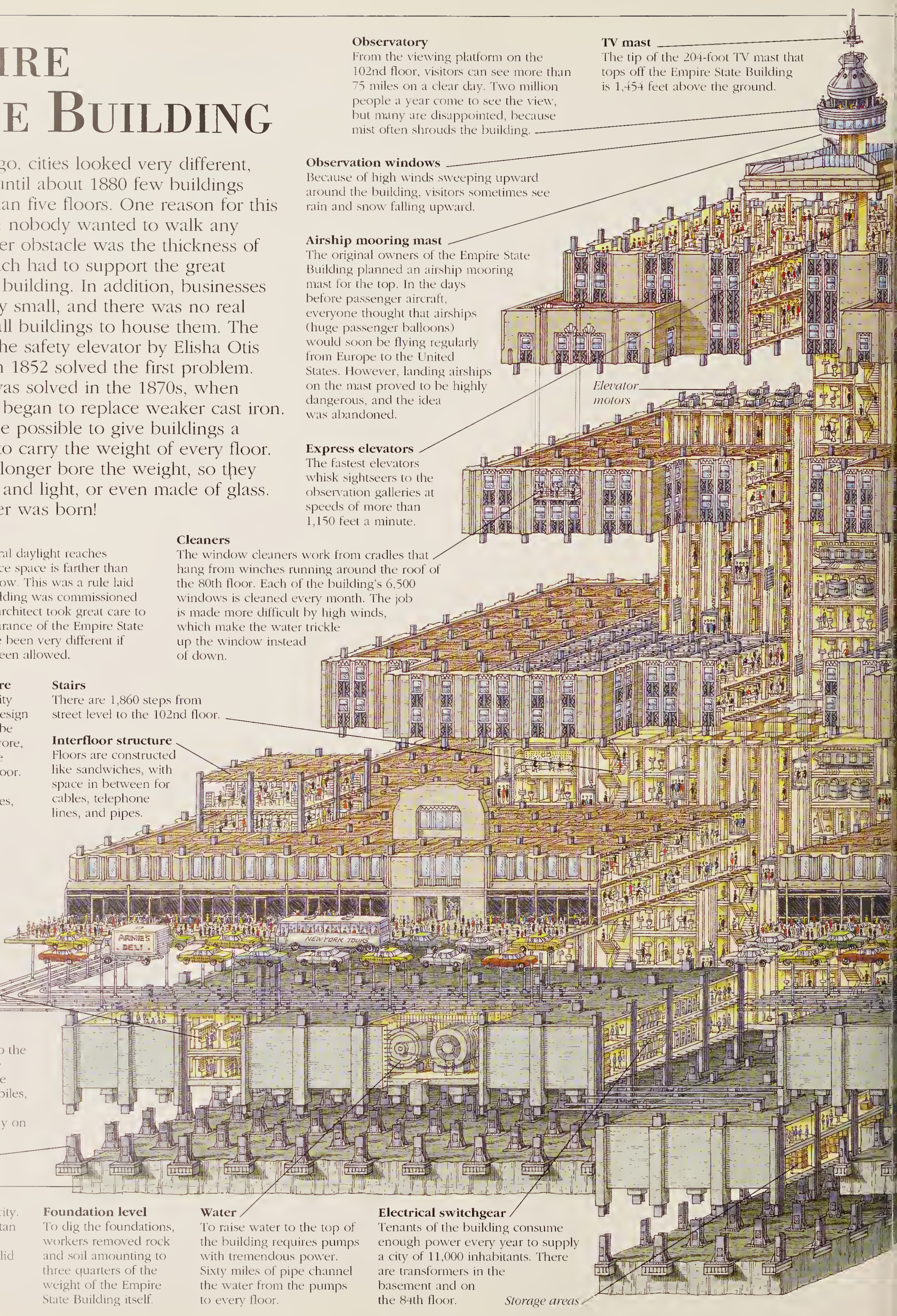
Propeller
Blades on the propeller have variable pitch: their angle can be changed to control the ship's speed.

Cod liver oil tank
Gutting and filleting fish creates a lot of by-products, and this ship has a large tank that can store more than 44 tons of cod liver oil.

Steering-gear compartment
Apparatus in the steering-gear compartment operates the rudder, controlling the course (direction) of the ship.

EMPIRE STATE BUILDING

Not long ago, cities looked very different, because until about 1880 few buildings rose higher than five floors. One reason for this was the stairs: nobody wanted to walk any higher. Another obstacle was the thickness of the walls, which had to support the great weight of the building. In addition, businesses were generally small, and there was no real demand for tall buildings to house them. The invention of the safety elevator by Elisha Otis (1811-1861) in 1852 solved the first problem. The second was solved in the 1870s, when stronger steel began to replace weaker cast iron. It then became possible to give buildings a strong frame to carry the weight of every floor. The walls no longer bore the weight, so they could be thin and light, or even made of glass. The skyscraper was born!



Observatory
From the viewing platform on the 102nd floor, visitors can see more than 75 miles on a clear day. Two million people a year come to see the view, but many are disappointed, because mist often shrouds the building.

TV mast
The tip of the 204-foot TV mast that tops off the Empire State Building is 1,454 feet above the ground.

Observation windows
Because of high winds sweeping upward around the building, visitors sometimes see rain and snow falling upward.

Airship mooring mast
The original owners of the Empire State Building planned an airship mooring mast for the top. In the days before passenger aircraft, everyone thought that airships (huge passenger balloons) would soon be flying regularly from Europe to the United States. However, landing airships on the mast proved to be highly dangerous, and the idea was abandoned.

Express elevators
The fastest elevators whisk sightseers to the observation galleries at speeds of more than 1,150 feet a minute.

Office space
To ensure that natural daylight reaches everywhere, no office space is farther than 28 feet from a window. This was a rule laid down when the building was commissioned (ordered), and the architect took great care to follow it. The appearance of the Empire State Building might have been very different if bigger rooms had been allowed.

Cleaners
The window cleaners work from cradles that hang from winches running around the roof of the 80th floor. Each of the building's 6,500 windows is cleaned every month. The job is made more difficult by high winds, which make the water trickle up the window instead of down.

Central service core
Much of the ingenuity that went into the design of the building can be seen in the central core, which rises from the ground to the top floor. The core carries the elevators and services, such as electricity, telephones, air conditioning, and plumbing.

Stairs
There are 1,860 steps from street level to the 102nd floor.

Interfloor structure
Floors are constructed like sandwiches, with space in between for cables, telephone lines, and pipes.

Mailroom
In the mailroom, workers sort mail that is delivered by chutes from every floor.

Piles
More than 200 piles (columns driven into the ground) support the weight of the Empire State Building. The piles, made of steel and concrete, rest directly on the bedrock 33 feet below street level.

Bedrock
New York was the original skyscraper city. At its center Manhattan is made of granite, which provides a solid foundation for the many massively heavy buildings.

Foundation level
To dig the foundations, workers removed rock and soil amounting to three quarters of the weight of the Empire State Building itself.

Water
To raise water to the top of the building requires pumps with tremendous power. Sixty miles of pipe channel the water from the pumps to every floor.

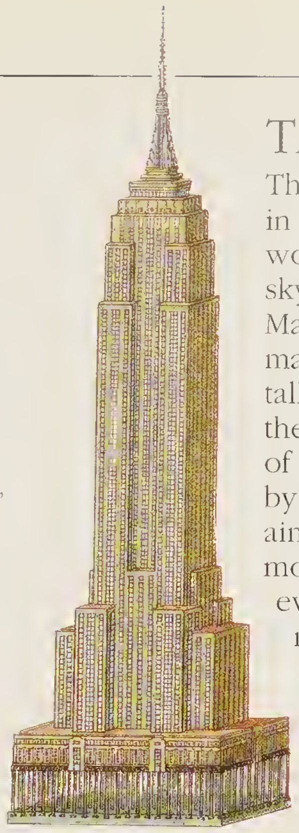
Electrical switchgear
Tenants of the building consume enough power every year to supply a city of 11,000 inhabitants. There are transformers in the basement and on the 84th floor.

Elevator motors
The positioning of the elevators was vital to the building's success. Too few elevators, and tenants could not get to their offices quickly enough. But each new elevator reduces the amount of office space to let. In the end, 73 elevators were built.

Steel floor frame
A network of horizontal steel girders built first provided a firm support for the concrete floors, which were poured on top and left to harden. Even at the time the frame was unnecessarily heavy — today only half the weight of steel would be used.

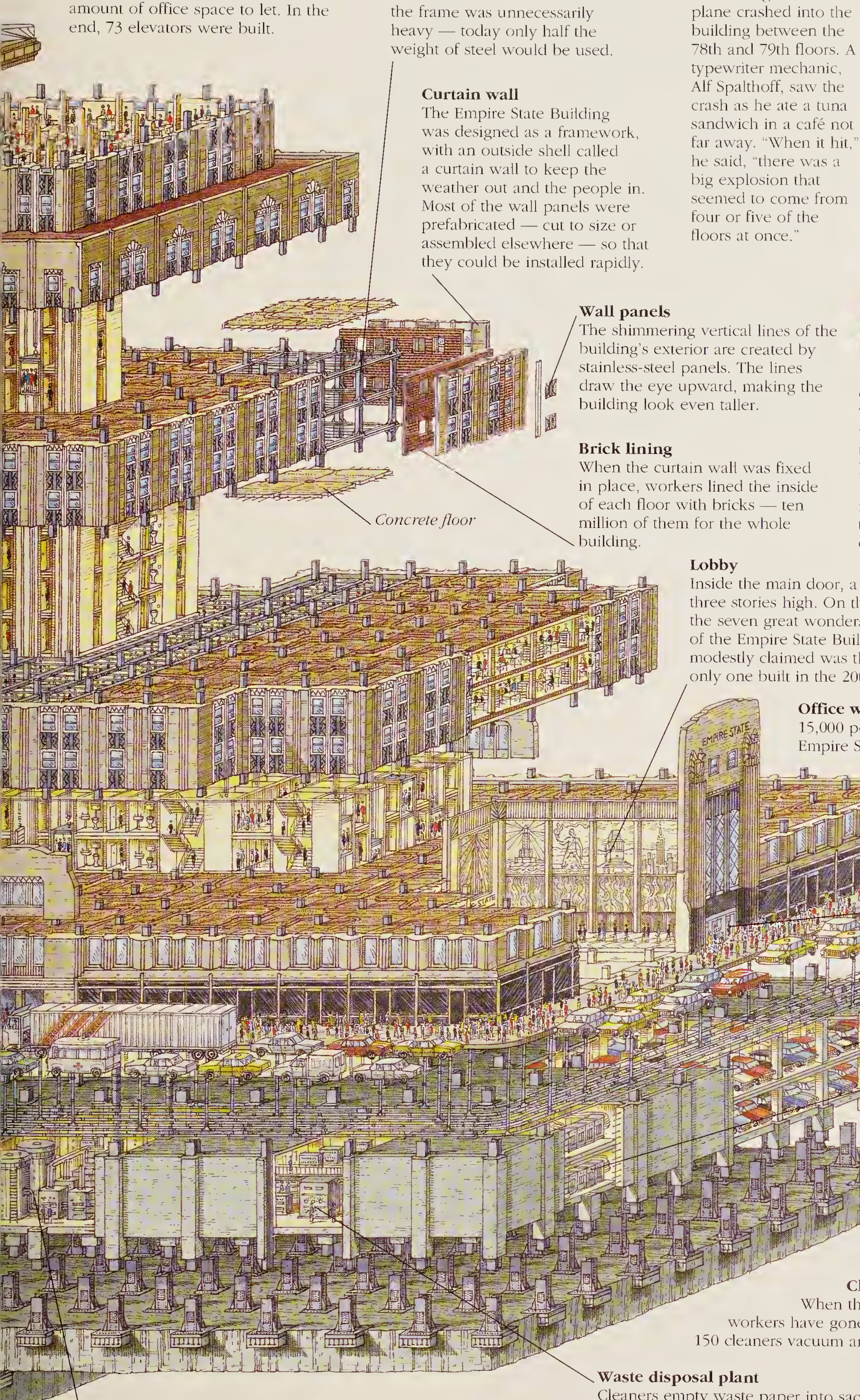
Curtain wall
The Empire State Building was designed as a framework, with an outside shell called a curtain wall to keep the weather out and the people in. Most of the wall panels were prefabricated — cut to size or assembled elsewhere — so that they could be installed rapidly.

Beacons
The Empire State Building has beacons to warn aircraft of its height, but on July 28, 1945, a fogbound plane crashed into the building between the 78th and 79th floors. A typewriter mechanic, Alf Spalthoff, saw the crash as he ate a tuna sandwich in a café not far away. "When it hit," he said, "there was a big explosion that seemed to come from four or five of the floors at once."



TALL TALE

The Empire State Building in New York City is the world's best-known skyscraper. Opened on May 1, 1931, it was for many years the world's tallest building. It was the creation of a group of business tycoons led by John Jacob Raskob. His aim was to commission the most beautiful skyscraper ever built — but also to make a lot of money by renting out the office space in the building, which stands on one of the city's most desirable sites.



Wall panels
The shimmering vertical lines of the building's exterior are created by stainless-steel panels. The lines draw the eye upward, making the building look even taller.

Brick lining
When the curtain wall was fixed in place, workers lined the inside of each floor with bricks — ten million of them for the whole building.

Get it up quick
The Empire State Building was completed in record time: 3,000 workers labored daily for less than 15 months to finish it. But in the rush to construct the building, 14 workers died in accidents.

Tenants' offices
The Empire State Building is an office building, with space rented out to tenants. When the building opened during the Great Depression, business in the United States was very bad, and the owners were at first able to rent only a quarter of the offices. New Yorkers dubbed it "The Empty State Building."

Lobby
Inside the main door, a magnificent lobby rises three stories high. On the walls are paintings of the seven great wonders of the world — and one of the Empire State Building, which the owners modestly claimed was the eighth wonder, and the only one built in the 20th century.

Power cables
More than 360 miles of cable supply power and light to office tenants.

Office workers
15,000 people work in the Empire State Building.

Main entrance
The Empire State Building is constructed so that the main door opens onto Fifth Avenue, New York's most fashionable street.

Utilities
Conduits, pipes, and cables under the street supply the building with gas, phone lines, water, steam, and electricity.

Steel skeleton
Building the Empire State Building's supporting framework required 52,780 tons of steel; 300 steelworkers completed the frame in 23 weeks.

Building materials
If a single train had brought all the building materials to the site, the caboose would have been more than 50 miles away when the engine arrived.

Cleaners
When the office workers have gone home, 150 cleaners vacuum and dust.

Air conditioning
Large buildings would be uncomfortable to work in without special heating and ventilation systems. The Empire State Building is air-conditioned by more than 5,535 tons of equipment in the basement, which pumps chilled water to air-conditioning units in every office. The air inside the building changes six times an hour.

Waste disposal plant
Cleaners empty waste paper into sacks and carry it to the basement in the service elevators. The waste is stored for a day in case someone has thrown away something valuable and needs to look for it. After 24 hours, the waste is compacted into bales weighing nearly 1,000 lb and taken away.

KEY FACTS

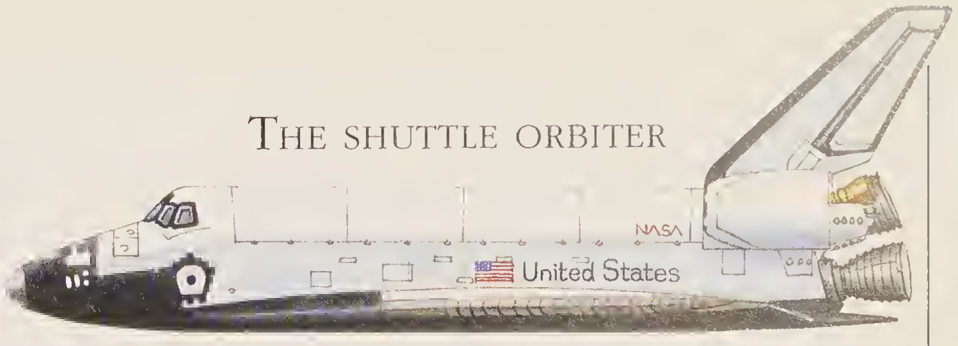
Height	1,454 feet (including TV antenna)
Weight	279, 410 tons
Ground area	9,336 square yards
Volume	36.75 million cubic feet
Floors	102
Stairs to top	1,860

SPACE SHUTTLE

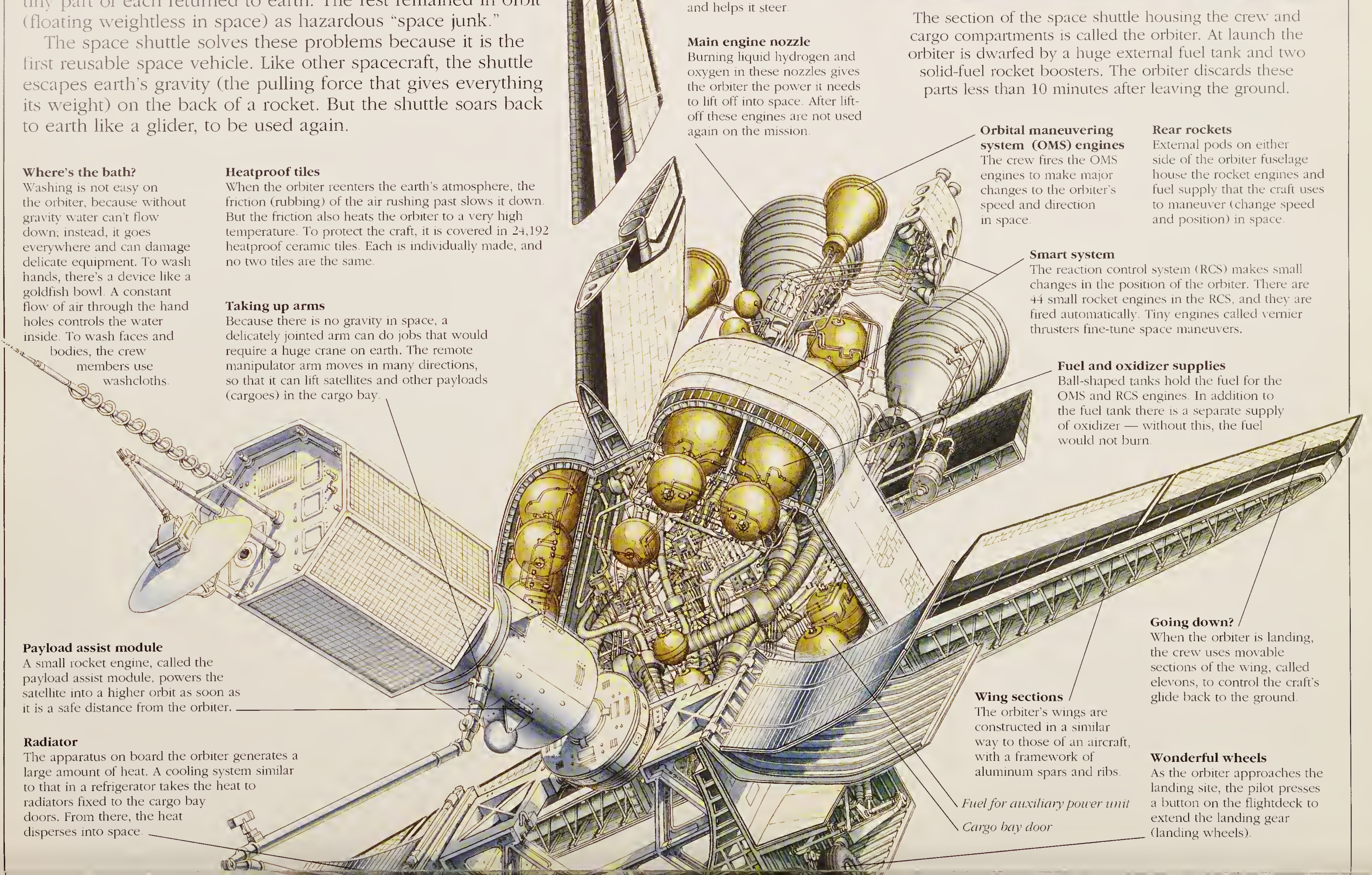
For centuries, people have dreamed of space travel. The dream came true in 1961, when space flights with human crews began. But soon the dream became a nightmare. Space vehicles are very expensive. And only a tiny part of each returned to earth. The rest remained in orbit (floating weightless in space) as hazardous "space junk."

The space shuttle solves these problems because it is the first reusable space vehicle. Like other spacecraft, the shuttle escapes earth's gravity (the pulling force that gives everything its weight) on the back of a rocket. But the shuttle soars back to earth like a glider, to be used again.

THE SHUTTLE ORBITER



The section of the space shuttle housing the crew and cargo compartments is called the orbiter. At launch the orbiter is dwarfed by a huge external fuel tank and two solid-fuel rocket boosters. The orbiter discards these parts less than 10 minutes after leaving the ground.



Where's the bath?
Washing is not easy on the orbiter, because without gravity water can't flow down; instead, it goes everywhere and can damage delicate equipment. To wash hands, there's a device like a goldfish bowl. A constant flow of air through the hand holes controls the water inside. To wash faces and bodies, the crew members use washcloths.

Heatproof tiles
When the orbiter reenters the earth's atmosphere, the friction (rubbing) of the air rushing past slows it down. But the friction also heats the orbiter to a very high temperature. To protect the craft, it is covered in 24,192 heatproof ceramic tiles. Each is individually made, and no two tiles are the same.

Taking up arms
Because there is no gravity in space, a delicately jointed arm can do jobs that would require a huge crane on earth. The remote manipulator arm moves in many directions, so that it can lift satellites and other payloads (cargoes) in the cargo bay.

Vertical stabilizer
Like the fin of an aircraft, the vertical stabilizer keeps the shuttle on course in the earth's atmosphere and helps it steer.

Main engine nozzle
Burning liquid hydrogen and oxygen in these nozzles gives the orbiter the power it needs to lift off into space. After lift-off these engines are not used again on the mission.

Orbital maneuvering system (OMS) engines
The crew fires the OMS engines to make major changes to the orbiter's speed and direction in space.

Rear rockets
External pods on either side of the orbiter fuselage house the rocket engines and fuel supply that the craft uses to maneuver (change speed and position) in space.

Smart system
The reaction control system (RCS) makes small changes in the position of the orbiter. There are 44 small rocket engines in the RCS, and they are fired automatically. Tiny engines called vernier thrusters fine-tune space maneuvers.

Fuel and oxidizer supplies
Ball-shaped tanks hold the fuel for the OMS and RCS engines. In addition to the fuel tank there is a separate supply of oxidizer — without this, the fuel would not burn.

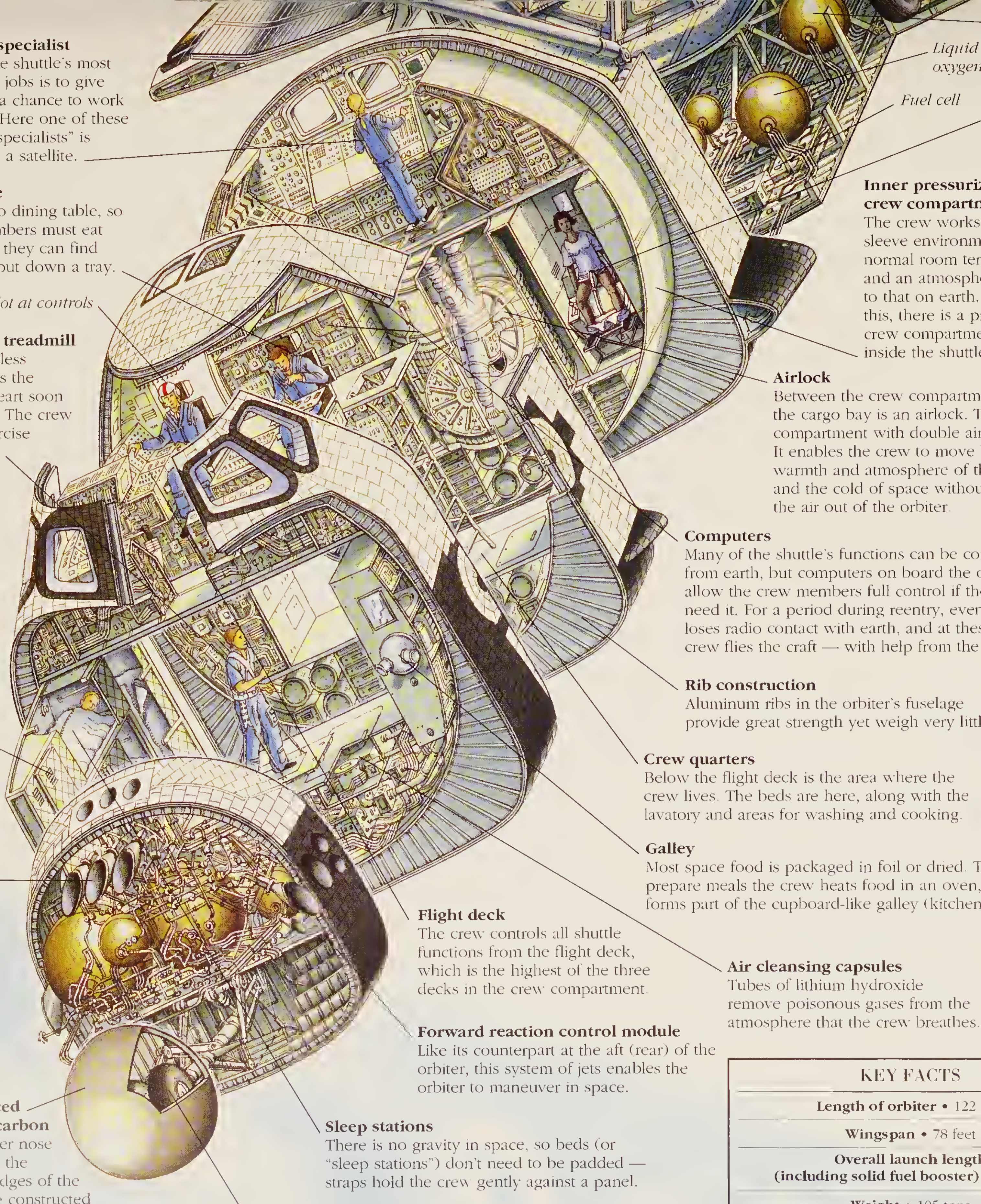
Payload assist module
A small rocket engine, called the payload assist module, powers the satellite into a higher orbit as soon as it is a safe distance from the orbiter.

Radiator
The apparatus on board the orbiter generates a large amount of heat. A cooling system similar to that in a refrigerator takes the heat to radiators fixed to the cargo bay doors. From there, the heat disperses into space.

Wing sections
The orbiter's wings are constructed in a similar way to those of an aircraft, with a framework of aluminum spars and ribs.

Going down?
When the orbiter is landing, the crew uses movable sections of the wing, called elevons, to control the craft's glide back to the ground.

Wonderful wheels
As the orbiter approaches the landing site, the pilot presses a button on the flightdeck to extend the landing gear (landing wheels).



Mission specialist
One of the shuttle's most important jobs is to give scientists a chance to work in space. Here one of these "mission specialists" is launching a satellite.

Mealtime
There's no dining table, so crew members must eat wherever they can find space to put down a tray.

Exercise treadmill
In weightless conditions the human heart soon weakens. The crew must exercise regularly.

Reinforced carbon-carbon
The orbiter nose cone and the leading edges of the wings are constructed of a material called reinforced carbon-carbon. This immensely strong material can withstand temperatures of 3,000°F.

Nose cone
The nose landing gear is stowed in the nose cone during the mission, extending only when the orbiter is ready to land.

Sleep stations
There is no gravity in space, so beds (or "sleep stations") don't need to be padded — straps hold the crew gently against a panel.

Forward reaction control module
Like its counterpart at the aft (rear) of the orbiter, this system of jets enables the orbiter to maneuver in space.

Flight deck
The crew controls all shuttle functions from the flight deck, which is the highest of the three decks in the crew compartment.

Inner pressurized crew compartment
The crew works in a "shirt-sleeve environment" — normal room temperature and an atmosphere similar to that on earth. To maintain this, there is a pressurized crew compartment built inside the shuttle fuselage.

Airlock
Between the crew compartment and the cargo bay is an airlock. This is a compartment with double airtight doors. It enables the crew to move between the warmth and atmosphere of the orbiter and the cold of space without letting all the air out of the orbiter.

Computers
Many of the shuttle's functions can be controlled from earth, but computers on board the orbiter allow the crew members full control if they ever need it. For a period during reentry, every mission loses radio contact with earth, and at these times the crew flies the craft — with help from the computers.

Rib construction
Aluminum ribs in the orbiter's fuselage provide great strength yet weigh very little.

Crew quarters
Below the flight deck is the area where the crew lives. The beds are here, along with the lavatory and areas for washing and cooking.

Galley
Most space food is packaged in foil or dried. To prepare meals the crew heats food in an oven, which forms part of the cupboard-like galley (kitchen).

Air cleansing capsules
Tubes of lithium hydroxide remove poisonous gases from the atmosphere that the crew breathes.

KEY FACTS

Length of orbiter • 122 feet

Wingspan • 78 feet

Overall launch length (including solid fuel booster) • 184 feet

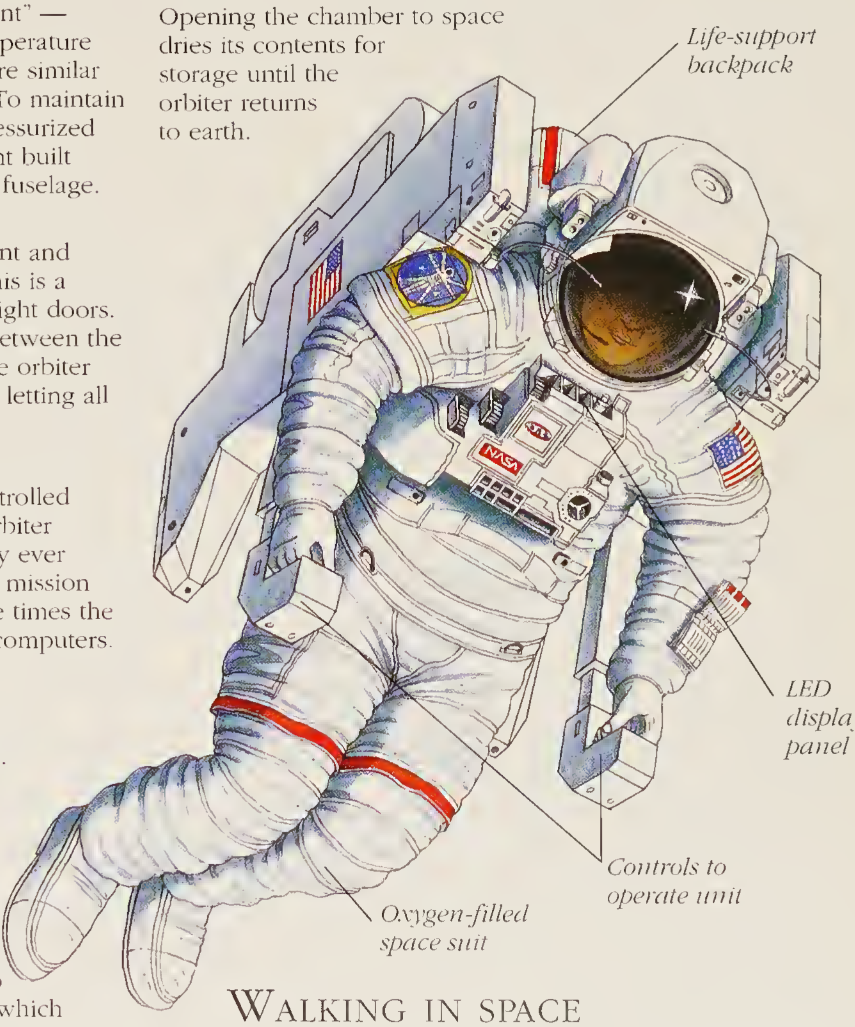
Weight • 105 tons

Payload bay area of orbiter • 15 feet x 60 feet

Cargo capacity (launched due E) • 27.5 tons

Waste collection unit
This is the name for a space toilet. Separate devices collect liquid and solid body waste. The hoselike device collects urine. Below the seat there is a slinger — a spinning shredder throws solid waste outward so that it sticks to the walls of a round chamber. Opening the chamber to space dries its contents for storage until the orbiter returns to earth.

Liquid hydrogen tank
To generate power for the electrical systems, there is a fuel cell which makes electricity by combining hydrogen and oxygen. A byproduct of the process is water, which the crew drinks.



WALKING IN SPACE

The crew may have to leave the orbiter to fix payloads or to carry out repairs in space. The crew calls these outings extravehicular activity, but most people on earth call them space walks. Crew members on space walks wear special suits and move around using a special maneuvering unit — a sort of flying armchair. They control their position in space by firing jets of nitrogen gas. The astronaut's spacesuit is filled with oxygen and has many layers to keep him or her warm. A backpack life-support unit filters harmful gases from the air the astronaut breathes and keeps the suit at a comfortable temperature. A chest-mounted LED display panel keeps the astronaut informed about factors such as fuel and battery status.

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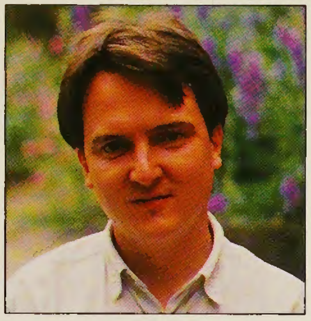

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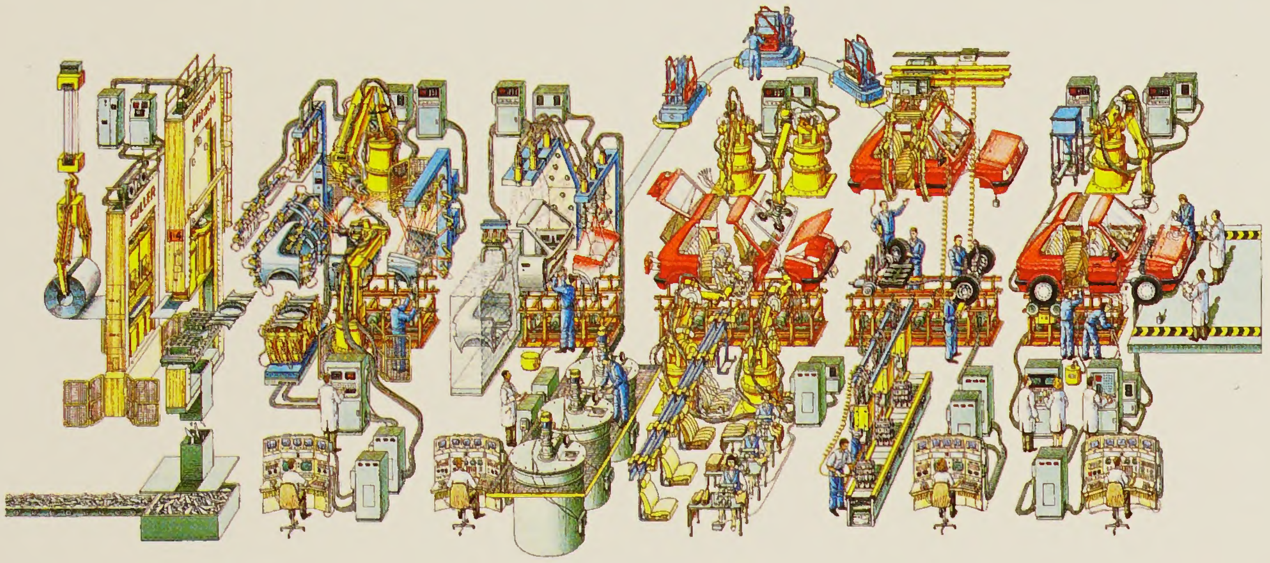
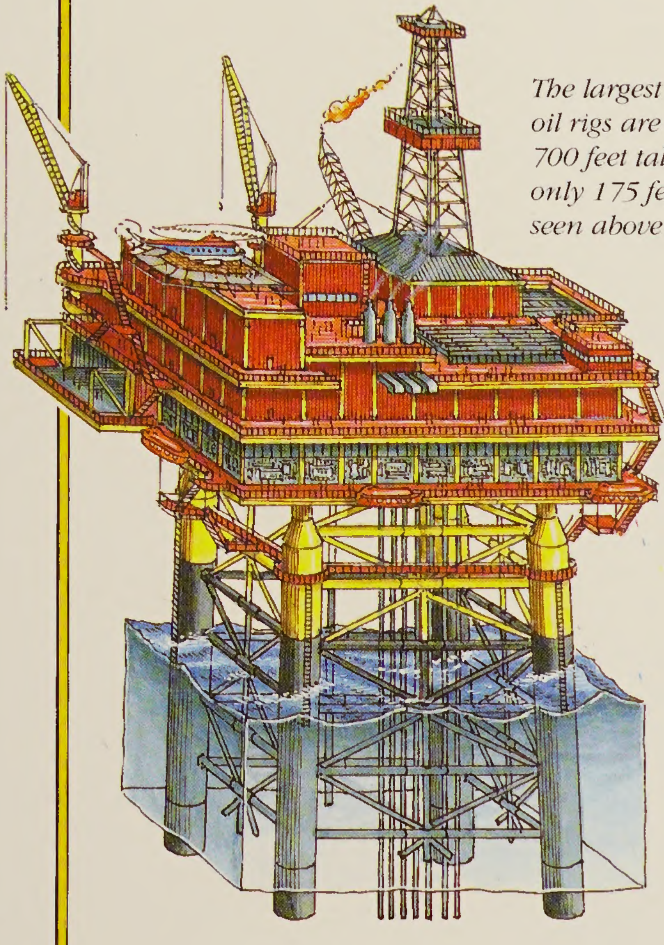
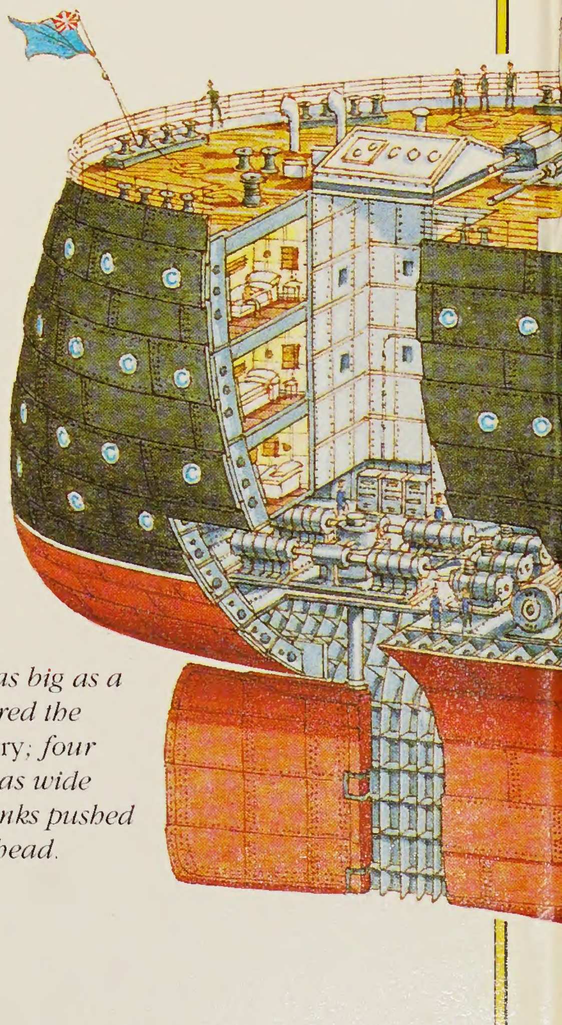
RICHARD PLATT studied graphic design in England and has worked as a writer, editor, and photographer since 1980. He was a contributor to *The Random House Children's Encyclopedia* and the author of *Film* in the Eyewitness Books series. He has written on topics as varied as ornithology and smuggling, and describes himself as a connoisseur of facts — from the useless and obscure to the fascinating details that have found their way into this book.



It takes 25 hours and more than 10 steps to paint a car body. After the final coat is applied, the car is baked in an oven at 320° F.



The largest North Sea oil rigs are over 700 feet tall, but only 175 feet can be seen above water.



A rudder as big as a house steered the Queen Mary; *four propellers as wide as tree trunks pushed the ship ahead.*

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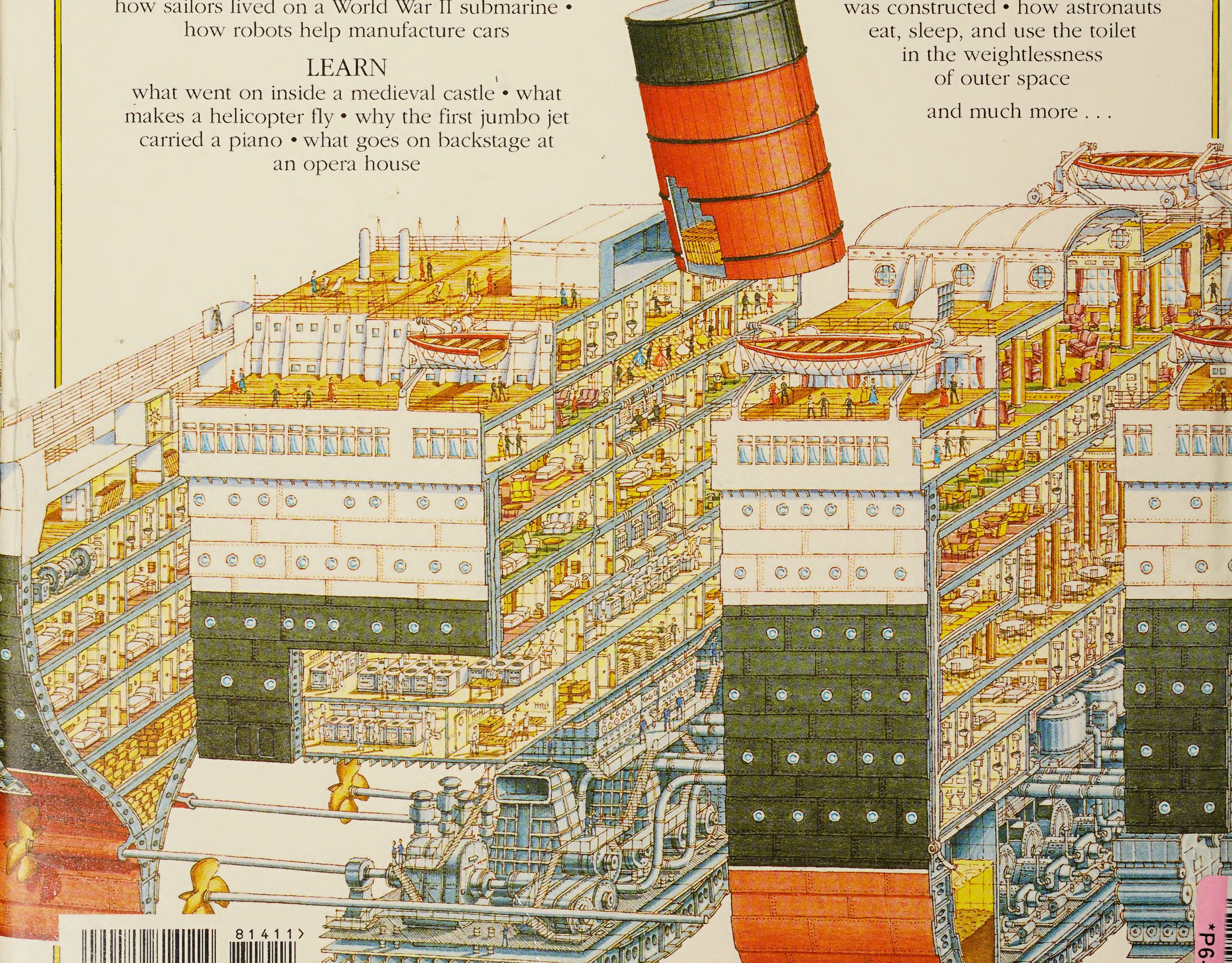

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